Don Lancaster's

Hardware Hacker

Selected reprints — volume II
Radio-Electronics series

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Introduction

In January of 1987, I moved my *Hardware Hacker* column over to *Radio Electronics* magazine with its larger circulation and its less archaic and infinitely less fascist editorial policies. This volume of reprints begins with the January 1988 column.

I have done a total new layout here, editing and updating when and where necessary, and combining all of the hard to find *Names and Numbers* together into one master file found at the end of the volume. A new cross-index is also included.

Naturally, 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 willing to do so in a fully cooperative, low cost, and sharing network environment.

While our focus is, and continues to be, on the traditional "stand-alone" electronic circuitry, most anything at all can and will pop up. I am especially strong on showing you all of the resources and tools that the others, for one reason or another, go out of their way to withold from you.

As to content, I go on the assumption that if I am interested enough in something to get involved with it, then others like yourself may also be. I refuse to limit myself to traditional or narrow categories of anything.

These volumes are also an ongoing experiment in *book on demand* PostScript laser printing. What you have here was literally beat out on a brick in my back yard. All of the figures, all of the artwork, and all of the text was done by using the *AppleWriter* word processor on an Apple IIe, and on-demand printed, one self-collating custom copy at a time, on an Apple LaserWriter. Binding is via a *Unibind* toaster, and shearing by way of "borrowed" time on a third party shear.

My ongoing thanks to *Radio Electronics* publisher Larry Steckler for letting me say what I want to say when and how I want to say it. To subscribe, call them at (516) 293-3000. ✥

About the Author

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

Microcomputer pioneer and guru Don Lancaster is now the author of 23 books and countless articles. He 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, he is considered by yet others to be the . . . er, better skip that one.

His monthly columns include both the *Ask the Guru* and *LaserWriter Corner* over in *Computer Shopper*, and his *Hardware Hacker* column in *Radio Electronics* magazine.

Some of his other titles include his *CMOS* and million-seller *TTL Cookbooks*, *Micro Cookbooks* volumes *I* and *II*, *Enhancing your Apple II*, volumes *I* and *II*, the *AppleWriter Cookbook*, the *Active Filter Cookbook*, *Apple Assembly Cookbook*, his *Ask the Guru* reprints, *Don Lancaster's PostScript Secrets*, and his *Intro to PostScript* video.

Don's current software offerings include his *PostScript Show and Tell*, and *PostScript Work in Progress*, plus a few companion disks for his various books.

Don is the head honcho of *Synergetics*, a new-age design and consulting firm that specializes in Apple computing, laser printing, *PostScript* program utilities, electronic prototyping, 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 welcomes your calls and letters. Best calling times are 8-5 weekdays, *Mountain Standard Time*. ❖

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Welcome to a brand new feature column here at *Radio-Electronics*. I'll be doing whatever I can here to find for you all the needed resources, answers, and opportunities for all you readers. While we will center mostly on traditional stand-alone electronics, nearly anything at all in the "neat stuff" category can and probably will come up.

You will find an end box listing a new and no-charge help line that you can call most weekdays 8-5 *mountain standard time* to talk to the guru his-self. In addition, all of the *Names and Numbers* mentioned in any column will be combined together into one common master listing.

Many of these resources are *very* hard to pin down. Considerable time and effort has gone into finding and verifying all of them.

And, from time to time, we will have a contest or two to close the loop and get you involved. Some of these will be technical and some not. The usual prizes will be a book of mine or an all expense paid *tinaja quest* (FOB Thatcher, AZ), possibly with some occasional extra cash for an outstanding entry. One hint: your odds of winning one of these are *very* good! Let's jump right in . . .

Automotive Electronics

There's an outfit called the *SAE* who used to be known as the *Society for Automotive Engineers* that have a very wide variety of books, technical literature, and other publications on just about anything vehicular.

While some of their stuff is rather pricey, there's lots of goodies in the $10 to $30 range. For their complete listing, be sure to ask for the current *1988 Publications Catalog*.

Some of the more interesting titles include *Commercial Vehicle Electronics*, *Some Unusual Engines*, *Audio Systems: Speakers and Receivers*, *Recycling of Automotive Catalysts*, *Sensors*, *Understanding Automotive Electronics*, and *The History of the Internal Combustion Engine*.

They do have hundreds more, so be sure and check them out.

Non-volatile EEPOTs

Suppose you took a 100 position selector switch and 99 resistors of, say, 1000 ohms each. You could then connect all these up to make a 100 position volume control, as was done in the older broadcast-quality audio attentuators. Now, what would really be nice is finding some good way to *remote control* your switch settings. This way, you or a computer could change the switch position at will.

The switch would now be able to "remember" its previous setting and would still be correct the next time you applied power.

Well, the folks at *Xicor* have done you one better. They have come up with an 8-pin mini-dip beastie called an *EEPOT* that might be used as a remotely controlled volume control. You can also think of it as an unusual digital-to-analog converter or else as a multiplier that can multiply both a digital and an analog value together.

Three of the available devices now include the *X9103* (10K), the *X9503* (50K) and that *X9104* (100K). *Xicor* has been known to send out free samples on all your letterhead requests; otherwise, these cost under $5.

Figure one shows you the block diagram of an EEPOT. A pair of leads are used for the +5 volt DC supply and ground. Three leads are used for the two ends and the wiper of the equivalent potentiometer. Finally, the three leads known as *chip select*, *up-down*, and *increment* are used for the digital control.

The position in the resistor string is selected by one of the 100 internal field effect transistors connected as data selectors. The present position is remembered by a seven bit, modulo-100 counter. Whenever the chip gets selected, you can raise or lower the position one count at a time, through use of the *up/down* and *increment* inputs. The EEPOT will "stick" at the highest or lowest settings to prevent

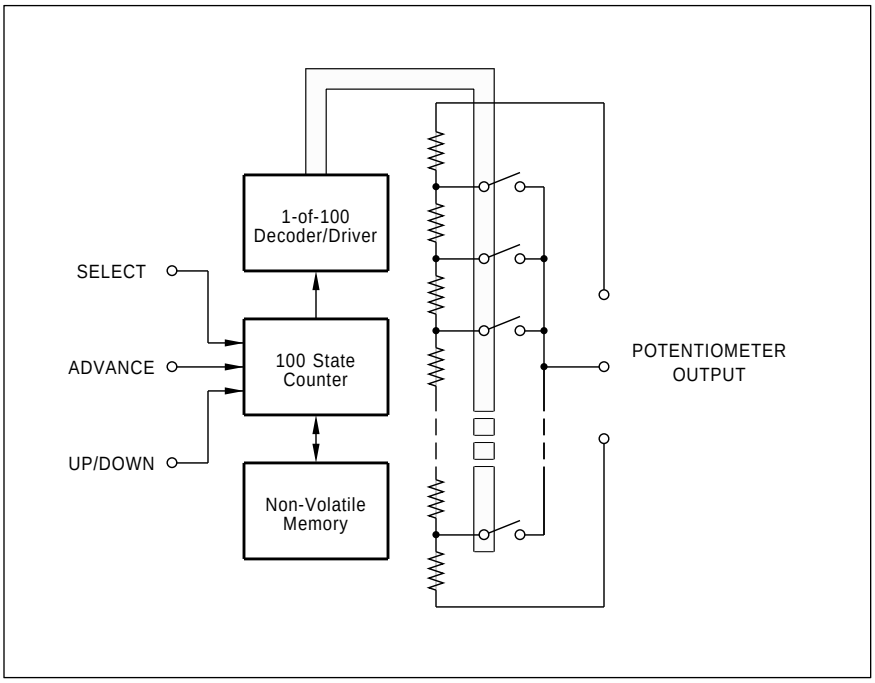


Fig. 1 – An EEPOT can simulate any ordinary potentiometer that might be remotely controlled, either manually or by a computer. The wiper position is remembered during unpowered times by an internal non-volatile memory.

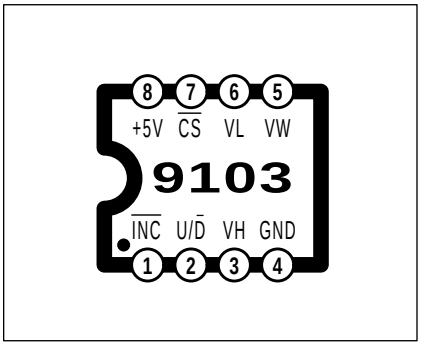


FIG. 2 – EEPOT Pinouts. VL, VW, and VH are the terminals for the output potentiometer. The $\overline{CS}$ chip select is brought low to change the wiper position, but is otherwise left at +5. The position gets changed by bringing $\overline{INC}$ first low and then high again, with the direction set by the up-down pin U/$\overline{D}$. A high on U/$\overline{D}$ will advance the position.

any wraparounds that could end up giving you disastrous results.

To initially preset your volume control position, you bring the chip select low. If you ever want a louder output, you make the up/down input high and then pulse the increment line by bringing it low and then back high again exactly once. Repeat for each step as needed.

Now for the neat part. The internal position counter gets "backed up" by seven internal non-volatile memory cells. When you deselect by making your *chip select* high, the memory cells "remember' the counter position for you, even after the supply power is disconnected. Thus, if you use this beastie to remotely set the volume on your stereo, you will have the same volume setting the next time you do apply power.

There are a few gotchas, though. While a hundred positions is more than enough for most audio uses, this just plain is not nearly enough resolution for such things as remotely setting a floppy disk drive's speed. Yes, it is possible to cascade 10K and 100K devices for greatly increased resolution, but you still might not get the absolute accuracy you need.

While the output distortion is quite low, you are limited to a maximum of + or 15 volts for the analog input signal. And you should not try to source or sink any more than half a milliampere of output current.

There is one *very* important use rule: *You absolutely must not ever disconnect the supply power while the chip is still selected*. As is typical with most non-volatile memories, powering down while active can lead to memory values being trashed.

You also will have to keep chip power applied when you are actually using the output. Thus, while we do have a low power device, it is not suitable for truely micropower uses.

Figure two shows you the pinouts, while figure three will show you a "bounceless" pushbutton that will let you experiment with the *increment* input on your EEPOT without needing anything at all fancy in the way of computers or test gear.

A bounceless switch is also shown you for use with the *chip select* input. Note that debouncing is absolutely essential for these two inputs if you are using mechanical contacts.

The *up/down* input does not need any mechanical contact debouncing, provided you wait a few milliseconds each time you change it.

In the real world, you are more likely to use the "already clean" and parallel outputs of a personal computer port or the output commands from a remote controller integrated circuit to drive your EEPOT. In these cases, any extra debouncing circuits are not at all needed.

Note that either analog or digital signals may be routed through the output potentiometer. The only rule is that you must stay within plus or minus five volts of ground.

To initialize to a known condition, simply downcount by 100 pulses or more to force a zero. Then count up to the needed value.

Now, I could sit here and tell you all of the marvelous things you can do by using a volume control whose settings are remotely and digitally controllable and then later remembered during the power down times. Things like variable gain amplifiers, self-calibrating instruments, electronic multipliers, and similar stuff.

Instead, we'll use the EEPOT for our first contest. Just dream up a good use or two for this chip. Be sure to send your entries directly to me via the address in the end box, and *not* to *Radio-Electronics* editorial.

Trade Journal Resources

Trade Journals are far and away the most important resource available to any hardware hacker, yet I still get countless helpline calls from people who have never even heard of them.

Just about any technical field has its own unique set of special interest magazines that are intended strictly for "insiders". These magazines are often free, but are rarely advertised, and are seldom seen on newsstands. Inside a trade journal, you will find ads for the latest and the best, both technical and survey articles, the year- end directories, bingo cards, and for various assorted freebies.

There are now many thousands of different trade journals that are being published today. Some important electronic examples do include *EDN*, *Electronic Design*, *Electronic News*, *E.E. Times*, *Power Conversion* and *Electronics*. Several of those great journals on robotics include *Machine Design*, *Design News*, and *Motion*.

To emphasize the wide variety of stuff that is available, several other trade journals that I have found personally useful include *Signcraft*, *Textile World*, *Printing Impressions*, *Technical Photography*, *Electronic Publishing*, *Computer Reselling*, and *Fire Engineering*.

So, just how can you tap all these resources that are absolutely essential for serious hacking? First, go to your local library and check into a most useful reference book called *Uhlricts Periodicals Dictionary*. This, and the similar *International Standard Periodicals Dictionary*, will give you a fairly complete list of exactly what is available from whom.

If you already do have your own business letterhead (an *absolute must* for serious hacking, and now utterly trivial to get in these days of laser printers), the next step is to write or call the various journals and ask for a reader qualification card. Chances are you can easily qualify for a free subscription. Try it and see.

If not, check any larger technical library, or see if some engineer at a larger electronics outfit can cop you older issues, or else use the good old *interlibrary loan service* available at any branch library.

But do not ever ignore those trade

journals. They represent far and away your most valuable resources for any serious hardware hacking. Collect them all.

The Santa Claus Machine

Yes, Virginia, there really is a new Santa Claus machine. It exists here and now, and represents enough new hacking opportunities to last you a lifetime or two.

Most of the science fiction authors, including *Hugo Gernsback*, at one time or another introduced a Santa Claus machine. Which was either a mass teleportation device or else an elemental atom smasher and rearranger. All you would have to do is feed it the correct set of plans, and out would pop a sports car, an oscilloscope, a roast beef dinner, or, for that matter, a brand new girlfriend.

As many copies as you like, even. Might as well print us up some $20 bills while we're at it.

Believe it or not, this type of Santa Claus machine exists today, albeit a very expensive one with very limited capabilities. While you can not yet duplicate the exact *function* of any object, you can in fact duplicate its exact *form*, and do so anywhere in the world, given a phone line and the right set of plans.

The idea is both very simple and astoundingly profound. You select either a tray (2-D) or a tank (3-D) full of an ultra-violet curing plastic called a *photopolymer liquid resin*. This resin is related to the uv curing resins already widely used by dentists, by printers, and by rubber stamp people.

Then you create a very small spot of ultraviolet light, either from your laser or from a special uv bulb and some optics. You move this light spot around as needed to *harden* any desired object out of the liquid resin. For 3-D objects, you might place an "elevator" on the surface of the liquid and then slowly lower the elevator so that layers are applied as needed to build up the final object.

You can very easily machine the unmachinable with this device. Such things as perfect and hollow spheres, blind undercut square holes, or very complex turbine blades having compound curves are utterly trivial.

While all the current Santa Claus machines are limited to a very few plastics, once you have made one prototype, you can easily make more molds, pantagraph copies, or whatever from it, ultimately converting it to most any material.

You can also think of Santa Claus machines as the next giant step beyond laser printing. With your Santa Claus machine, you could create a replica of a three dimensional object, while today's printers are essentially limited to two dimensional images using ink or toner.

Think of it. A $500 package beside your personal computer that can create a 3-D model replica of *any* object. Any object at all.

So what does all of this have to do with you? Just this: Here is a most incredible new opportunity in a brand new field that you can experiment with in a home lab or even on your kitchen table.

The leader in this new field seems to be an outfit called *3-D Systems*, while one source of the uv curing photopolymeric resins is *Meragraph*. The actual machines sell for $70,000 and $125,000. These prices are dirt cheap "must-have" bargains to the automotive people and other large manufacturers who can now make all of their molds and prototypes in 36 minutes instead of 36 weeks. This is literally an offer they cannot refuse.

What might we do on a hacker's budget? I don't see any reason why a low end and restricted performance Santa Claus machine cannot be built up for well under $300.

Figure four shows how I would go about it. First, I would initially stick with two dimensional objects such as letters, nameplates, bezels, or whatever. That third dimension just adds complications at a time when getting the basic process working any way at all should be your foremost goal.

Second, I would flush the laser and the beam scanning stuff, replacing the laser with a scientific ultraviolet lamp from *EG&G* or whoever, and replacing all the beam scanning with two linear steppers such as the *Hurst* type SLS or something similar.

And, third, I would not worry too much about complexity or speed. If it takes a week to machine a simple part, so what? Particularly if you are now about three orders of magnitude cheaper than your competition.

There are some highly important safety considerations in all this. The resins must be used only in a very well ventilated area, and you should avoid breathing any and all fumes. Touching or handling the uncured resin is also a very bad idea.

Even worse, the intense ultra violet light can easily cause blindness. That is why all of those elaborate interlocks are present on EPROM erasers.

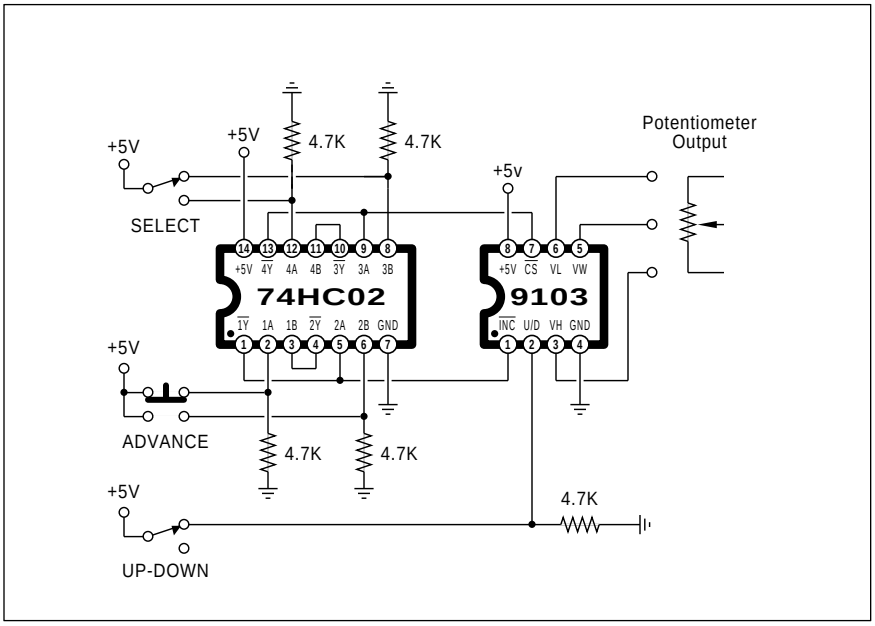


Fig. 3 – Use this circuit to test your EEPOT. The debouncing shown is only needed when you are using mechanical contacts.

Your Santa Claus machine should be totally enclosed inside an opaque shield. Experiments on focusing or whatever should be done on a trial and error basis only.

Do *not*, under any circumstances *ever* look at that ultra violet spot! I will also recommend wearing heavy sunglases as an additional precaution against an inadvertent powering of the lamp with your shields down.

Needless to say, the editors here at *Radio-Electronics* will pay very well for construction details on the first Santa Claus machine that can make non-trivial replica models and do so on a hacker's budget.

New Tech Literature

This would seem to be a very good month for technical data books. Data books usually contain highly detailed specificaions on electronic devices, often with accompaning application notes and use hints. The price of a data book varies from free to optional to nominal, depending on the manufacturer, who you are, and how you ask for the book. Once again, you get the best results with your own laser printed business letterhead.

Data books are a resource second only to trade journals in their usefulness to all you hardware hackers. The best rule is 1 collect them all!

At any rate, there are some real winners this month. Start out with the *Texas Instruments* Interface Circuits data book, plus that new *Sprague* Integrated Circuits data book, and then check into the *Advanced Micro Devices* data book on Bipolar and MOS memories.

Hewlett-Packard has a pair of new publications out, one called their Microwave and RF Designers Catalog, while the other new one is their Optoelectronic Designer's catalog.

And *Motorola* has checked in with their new Telecommunications Device Data book, containing plenty of hard-to-find information on all their integrated circuits for telephone use.

Turning to my own products, I do stock autographed copies of most of my own books as a special service to all of you *Radio-Electronics* readers. For the insider secrets on integrated circuits, there's my *CMOS Cookbook* and my *TTL Cookbook*. For the real lowdown on microprocessors, check out my pair of *Micro Cookbooks*, volumes I and II. You can write or call for a complete list, along with some hard-to-find "free stuff" info.

Do feel free to write or call over anything that is even remotely worth hacking over. This is your column and your feedback is essential to make it the best possible. Let's hear from you. Best calling times are 8-5 weekdays, *Mountain Time*. ✧

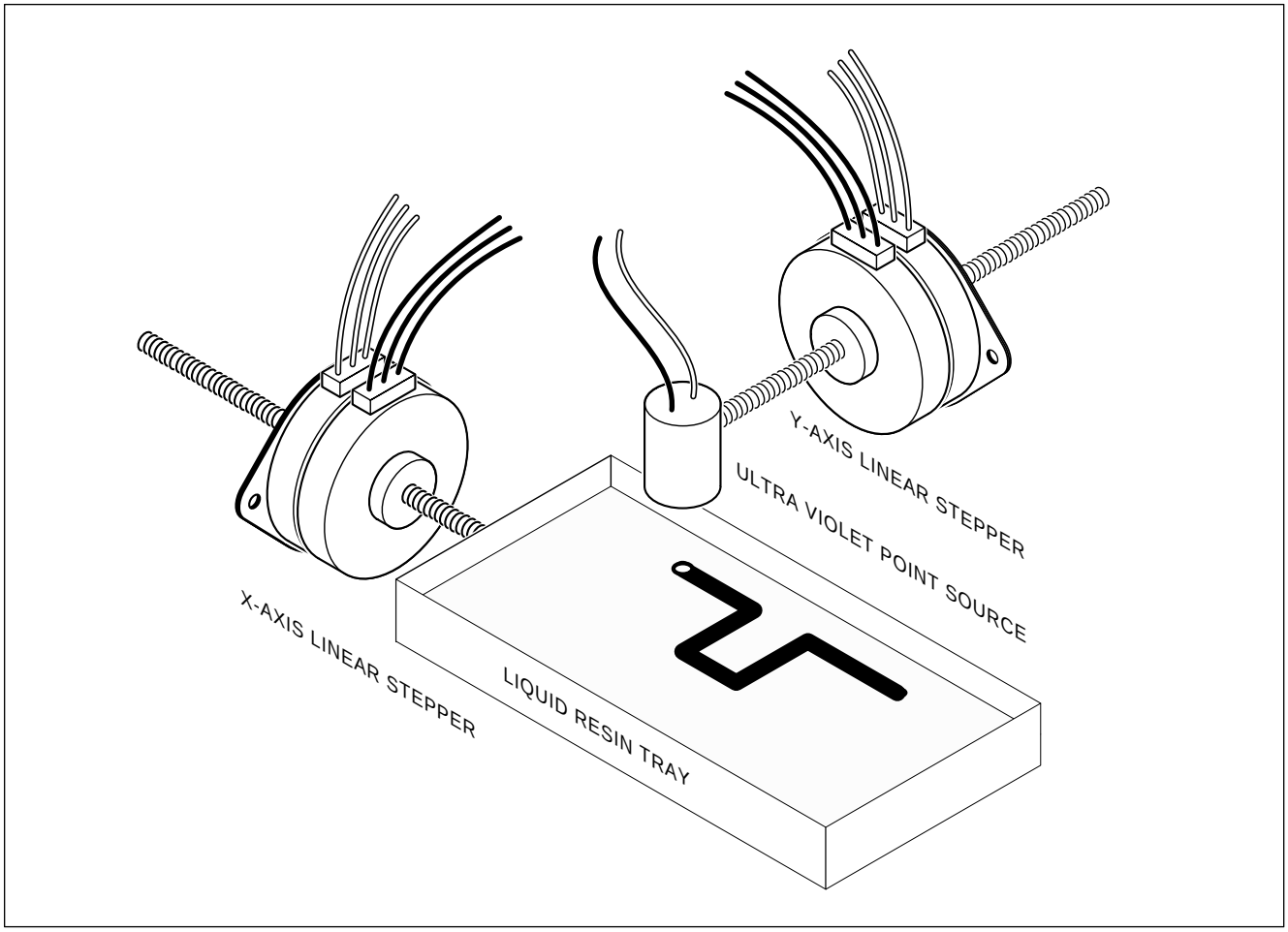


Fig. 4 – A two-dimensional santa claus machine can create a replica of virtually any flat object through the selective ultra-violet hardening of a liquid plastic photopolymer resin. Any object can be created anywhere in the world.

Don Lancaster's

Hardware Hacker

February, 1988

More on uv curing resins
Using liquid level detectors
Circuits for electronic music
Microprocessor fundamentals
Off-the-shelf superconductors

Hello once again. Welcome to release number two of my brand new *Radio-Electronics* feature column. As we found out last month, we will be exploring all sorts of "neat stuff" hacker opportunities here, electronic and otherwise. We will start off with a reminder that you can get some no-charge technical help per the number in the *Need Help* box shown at the end of this volume.

I have found out a little more on suitable u-v curing resins for that Santa Claus machine we looked at last month. It turns out a leading manufacturer of photopolymerization resins is *Hercules Chemical*.

One fairly cheap and easy to get u-v curing resin of theirs is used for making rubber stamps. This uv liquid resin is rebranded by the *Merigraph Systems* people as their own product *MD-035*, and is distributed by the *R.A. Stewart*, folks among others.

The really big news this month is that all of you hardware hackers can now buy superconductors right off of the shelf . . .

The New Superconductors

Whenever you cool certain metals or magic ceramic oxide compounds to an extremely low temperature, a very remarkable thing happens. Some of these materials will go into a new *superconducting* state where they will lose all their internal electrical resistance. At the same time, all of their internal magnetic fields will also drop to zero.

The numerous potential uses for new superconductors can boggle the mind. Utility electrical power could now be distributed long distances without any transmission loss. Much stronger and cheaper magnets for electric automobiles, transportation, atomic particle research, and biomedicine would revolutionize each of these fields. Computers could be made much faster and much smaller. So would new test instruments.

Until recently, all the temperatures needed for superconductivity were so cold that only rather expensive and cumbersome liquid helium could be used. But, within the last year, a new class of ceramic oxides consisting of copper, oxygen, and some rare earth elements were discovered that were now able to show superconductivity at much higher temperatures.

These new ceramic materials will superconduct in the 80 to 100 degrees Kelvin range (-173 to -193 degrees Centigrade). While this still remains extremely cold, you might easily hit these temperatures using cheap old liquid nitrogen in a styrofoam cup. Liquid nitrogen is available at less than draft beer prices from most any industrial gas supply house.

Better yet, there are now hints of superconductivity showing at much higher temperatures, some of which even approach room temperature. But these new developments are not yet confirmed or proven, and the whole field is still up for grabs.

In fact, all of the entire future of electronics hinges on all of the new superconductor research being done worldwide today.

Believe it or not, you can run out right now and buy your own superconductor to play with for only $8. One source is *Laboratory Specialists*.

What you get is not all that great lookng. Your superconductor is the size, color and shape of a pool cue tip. It is also extremely sensitive to any moisture or to any oxygen when it is at lower temperatures, so it can easily be degraded or destroyed. Just about all you can really do with it is demonstrate the fundamental superconductor properties 1 a zero internal magnetic field and a zero resistance.

On the other hand, this seems to be a guaranteed instant winner for your next school paper or science fair.

Before we go on, though, let's talk some safety. You should treat liquid nitrogen as if it was molten steel. It will instantly frostbite any tissue it comes in contact with. Safety glasses are an absolute must. Splashing can cause instant and permanant blindness. You should also wear double layers of heavy clothing that cover as much of your body as possible.

Be sure to review all your frostbite first aid before beginning.

You must work in an extremely well ventilated area. While the liquid nitrogen is not in itself toxic, it will

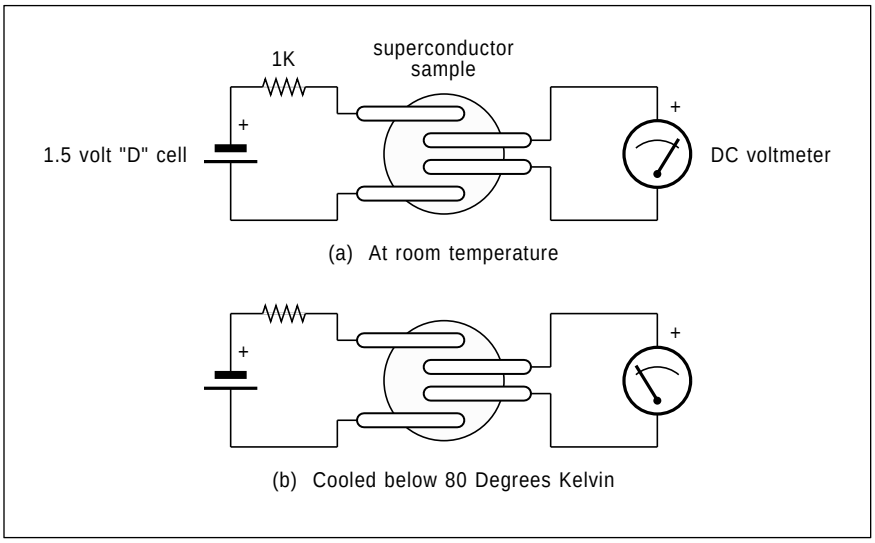


Fig. 1 – A test circuit to demonstrate the zero internal resistance properties of a cooled superconductor. The meter will show you zero voltage when your superconductor is below its critical temperature. The "four point" measuring scheme is used to minimize the effects of contact and lead resistance.

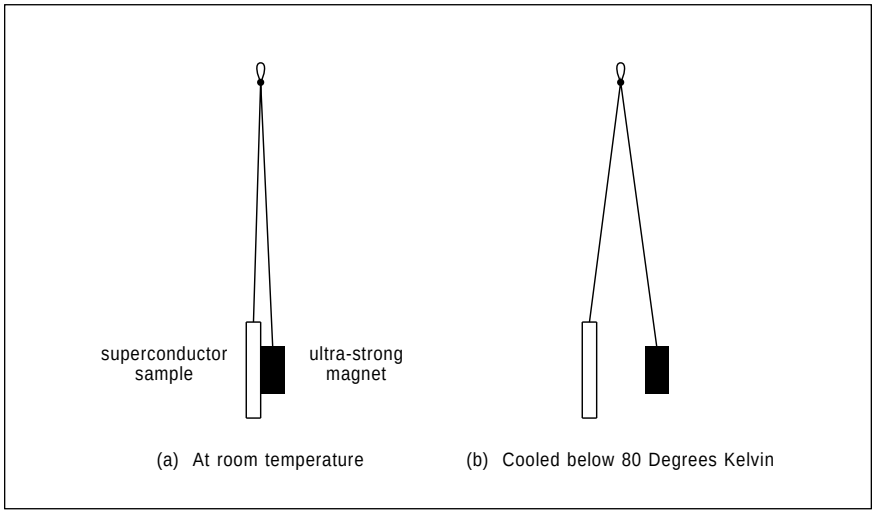


Fig. 2 – The Meissner Effect will produce a zero internal magnetic field in a cooled superconductor. The resulting field distortion will deflect (or can even levitate!) an extremely strong magnet as shown.

displace oxygen in any confined area and can cause suffocation. Just confining the liquid nitrogen can cause a pressure explosion, so a loose fitting lid must be used on any and all non-approved containers.

Many common materials will instantly shatter at the liquid nitrogen temperatures, so your safest low cost container will often be a plain old styrofoam coffee cup.

Yet another danger with supercold temperatures is that any liquid oxygen which condenses out can become a quite serious fire hazard. Uh, are you still there? Hello. Hello . . .

Actually, when treated with both common sense and respect, all of the dangers of liquid nitrogen handling are no worse than, say, using a power lawnmower or a radial arm saw.

Figure one shows us how to demo superconductivity. Basically, you set up your superconductor as a voltage divider and then measure the output voltage. When you slowly lower the sample into the liquid nitrogen, your output voltage will drop to zero, thus proving that the material is in fact superconducting.

Figure two shows you a method to demonstrate yet a second measure of superconductivity. This is called the *Meissner Effect*. The Meissner effect says that you will get a zero internal magnetic field when you are actually superconducting.

This effect does require a special, extra strength neodymium-iron-boron magnet. Actual physical levitation of your magnet is not usually possible with these low cost samples.

For more information, and for additional cautions, be certain to carefully read the instructions that come with your superconductor.

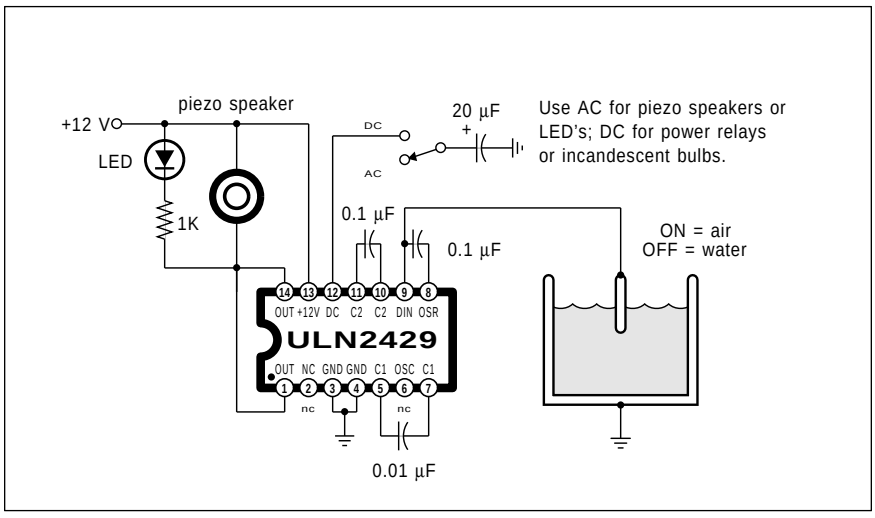


Fig. 3 – The Sprague ULN 2429 is an automotive liquid level detector that has plenty of hacker potential. Here is the basic test circuit using a pop can full of tap water as a liquid level sensor.

Brewing Your Own

Doing your own superconductor research can get rather tricky for the average hardware hacker, but it is certainly not out of the question. The basic technology involved is pretty near as complicated as microwaving a pan of brownies.

And a nobel prize is up for grabs for the first confirmed and verifiably stable room temperature superconductor. Not to mention a *very* big bag of nickels. Dimes even.

First and foremost, you should be a lab type person, and have access to either a school chem lab or else have your own *very* advanced home lab.

Second, of course, would be a very healty respect for all the dangers of working with all these extremely low temperatures. Once again, the safety glasses, heavy double clothing, good ventillation, and everyday common sense are essential.

Third, you would need reprints of many of the current papers in superconductivity. While there are some expensive new journals out, check into *Physics Abstracts*, *Science*, or, best of all, the *Dialog* on-line technical and scientific information BBS utility. All of these resources should be available at most better schools and libraries.

Two of the rather good technical resources to get you started are the special superconductor issue of *Physics Today*, 39, #3, 1986, and Bednorz and Muller's classic paper in *Science*, Volume 237, pages 1133-1139.

And, finally, you will need a good source of raw materials. The *AESAR* people have long been a good source of small quantities of the high purity metals, compounds, and elements. They have just released a brand new

superconductor materials flyer that includes all the Barium, Strontium, Scandium, Copper, Lanthanum, and the Yttrium that are used in just the right combinations.

Cost ranges from $1 to $87 a gram in small quantities, depending on the material and its quantity.

Be sure to let me know what else you come up with in this brend new, exciting, and wide open new field.

Liquid Level Detectors

All of the automotive people have shown a lot of interest lately in fluid level detectors, particularly for low radiator water level warning systems. There are quite a few circuit manufacturers that offer specialized chips for liquid level detection.

One interesting and low cost liquid level detector is the unique *Sprague* ULN-2429A. This beastie is shown to you in figure three.

There are three basic areas to the circuit. These areas include a regulator, an oscillator, and a detector.

The first circuit area is a 6.4 volt regulator that isolates the rest of the internal electronics from any battery and vehicle noise. Because of this regulator, the intended supply is in the 10 to 16 volt range.

For hacker uses, you can run on a 9 volt battery, but with less stability and accuracy than running at the intended 12 volts. The current drain is under 10 milliameres, exclusive of any load current.

The second area is made up of a simple audio oscillator. You might change the frequency of this oscillator by changing the timing capacitor between pins 5 and 7. The intended operating frequency is 2.5 kilohertz, which can be used to directly drive an ceramic piezo squawker.

A simplified circuit of the audio oscillator is shown in figure four. This is a low power circuit, intended to work into a 10K or higher load. The output is a rather sloppy square wave with four volts of peak to peak amplitude.

A series output resistor is normally used with the oscillator. You have your choice of using an internal 18K resistor on pin 8, or else of adding your own external resistor on pin 6.

The third area forms the detector circuit shown you in figure five. This is basically a three stage amplifier that can work in two different modes. The detector will strongly amplify any audio signal which exceeds 1.2 volts peak to peak, but completely ignores anything weaker.

In the first mode, you amplify the 2.5 kHz or other audio signal and then directly drive a piezo transducer at the output. You can also drive a LED light emitting diode by use of this square wave.

There is one gotcha to driving a LED. You have to use a series resistor which sets the peak LED current *twice* normal, since the output square wave will only be on *half* the time.

Whenever you close your AC-DC switch of figure three, the output stage will become a high power DC driver, capable of driving a relay or an incandescent lamp. You might output as much as one ampere from this tough driver circuit, if you use a heatsink clip and be ceratin to connect *both* output pins 1 and 14 to a large printed circuit foil area, as well as connecting *both* of ground pins 3 and 4 to a similar large foil area.

That capacitor on pins 10 and 11 reduces the frequency response of the detector to whatever is needed, in addition to eliminating any possible high frequency noise.

If you input 1.2 volts peak to peak or less, the output stays *off*. If you input more than 1.2 volts peak to peak, the output turns *on*. While you can drive the detector input from the oscillator with up to a 1 meg resistor, the internal 18K resistor is both more stable and preferred.

How Does it Work?

Looking back at figure three, if the probe does contact the liquid, enough of the square wave will get shunted to ground, thus turning off your detector. Thus, when you are *contacting* liquid, the output is *off*. When your coolant drops below the probe, the output turns on.

The *Sprague* data sheet also shows a series double probe setup that turns your output on only when in contact with the liquid. But note that this alternate circuit will only work with isolated liquids that are not grounded. A liquid without a conductive or capacitive path to ground is highly unlikely in the real world.

Suitable liquids are tap water, sea water, weak acids and bases, coffee, wine, wet soil, or beer. Most distilled water, oils, dry soil, or vodka will not work reliably.

One of the reasons for using an audio signal rather than a DC voltage for a level sensor is to prevent any plating or electrolysis effects that can alter the sensor probe over time.

When you are working with tap water, there are three different forces at play. If you just shove your ohmmeter probes into a pop can full of tap water, you most likely will end up measuring something in the 5 to 20 megohm range. This, obviously, is

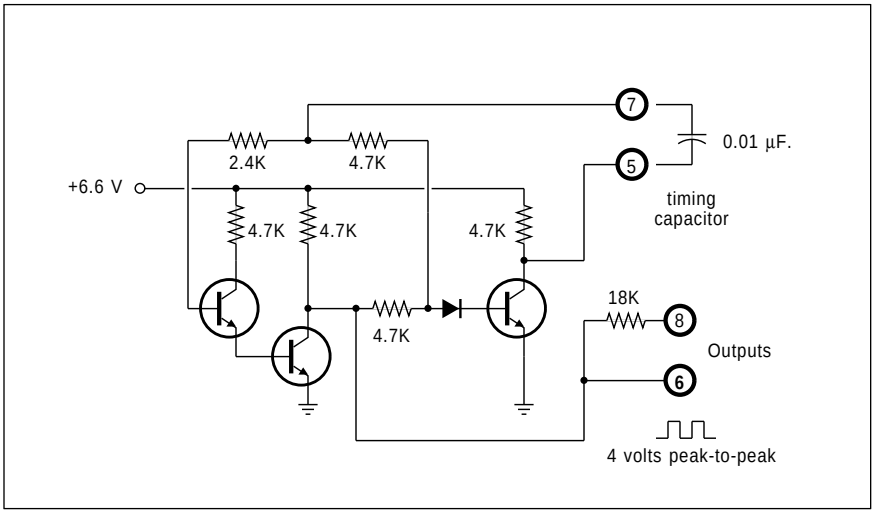


Fig. 4 – A simplified schematic of the internal audio oscillator found in the ULN 2429. The usual operating frequncy is 2.5 kiloHertz, and can be set by the external timing capacitor.

far too high to significantly shunt out the 18K resistor.

But water has a dielectric constant of 84. Thus, what might have been a 10 pf capacitor when the probe is in air becomes an 840 pf capacitor when immersed in water.

Finally, most any material has its *loss tangent*, which will tend to attenuate high frequencies more than low ones. Any ions floating around in the tap water will thus further lower the impedance for you.

This sure did have me fooled for a while. Intuitively, you would expect probed tap water in a pop can to look like something much higher than an 18K resistor at audio frequencies. But that triple combo of conduction, and an unusually high dielectric constant, along with an increasing loss tangent all gang up to let this simple circuit work like a champ.

Just because the chip is called a level detector does not mean that all us sneaky hackers can not do wildly different things with it. Think of the circuit instead as a simple audio oscillator along with a thresholding level detector with either AC or high current DC control outputs. Between the oscillator and detector, we have the options of making or breaking one series connection, or of shunting or not shunting some of the oscillator signal to ground.

So, for this month's contest, just dream up a brand new use for the ULN-2429A. Paper ideas are just fine; you do not have to actually test your circuit. There'll be one of my books to the best twenty entries, and an all expense paid (FOB Thatcher, AZ) *tinaja quest* to the best entry of all.

I'll eliminate the two most obvious new uses by presenting them here as examples: You can make a *continuity tester* by using those oscillator and detector leads to do such things as ringing out cables. By replacing the water sensor with a long wire, you can create a *burgular alarm* that trips whenever the wire is cut.

Let us see whatever else new and exciting you can come up with on this. Entries must be in writing.

Electronic Music Chips

As with anything electronic, there are two different types of the high performance circuits for electronic music, digital and analog.

The digital ones are used for such things as polyphonic and polytonic oscillators and envelope generators. One major souce of these is *Ensoniq*, whose chips are often used in many popular high end synthesizers. Their 5503 synthesizer chip is used in the Apple IIgs, and gives the IIgs far and away the finest sound available from any personal computer.

The analog chips used in electronic music are more traditional. These would include such things as voltage controlled oscillators, amplifiers, and filters. The *Solid State Micro Technology* (formally *SSM, or Solid State Music*) people seem to be the leader in this area. They have a free *Product Guide* you may want to send for.

One good source of further info is that *Electronic Musician* magazine, published by Craig Anderton. Do be sure to check this one out.

New Tech Literature

All those new data books are still continuing to pour in. Check out the *CMOS Data Manual* from *Signetics*, the new *CMOS/NMOS Special Functions* data book now available from *Motorola*, the really great *Pressure Sensor Handbook* from *SenSym*, and the new *Modem Design Booklet* from the folks at *Exar*.

As with most data books, the price varies from free to optional on up to nominal, depending on your supplier and how you ask for one.

For a rather useful new hacker structural material, do try *Gatorfoam* from *International Paper*. This flat, rigid, strong, and lightweight stuff is available in thicknesses from 3/16 to 1-1/2 inches and is much easier to handle and use than are most of the woods, wood substitutes, and all of the common plastics. This is ideal both for modelmaking and for any breadboarding. Some free samples are available on request.

Meanwhile, the folks at *Lindsay Publications* have a totally amazing book collection on everything from machine shop practice to perpetual motion machines to *Telsa* stuff to reprints of some very early shortwave radio construction projects. Virtually everything they stock is useful and hands-on. Many of their books are reprints of the "lost" mechanical and electrical art from long ago and far away. Neat stuff, all of it.

Several of you hackers have asked how to really get started into all the fundamentals of microprocessors and microcomputers. By one of those absolutely astounding coincidences, I just happen to have written my own *Micro Cookbooks*, volumes I and II. I do have a few autographed copies in stock here at *Synergetics* for you.

Send all of those contest entries directly to me, and not off to *Radio-Electronics* editorial. Entry or not, let's hear from you on our new help line. Best calling times are weekdays 8-5, *Mountain Standard Time*.

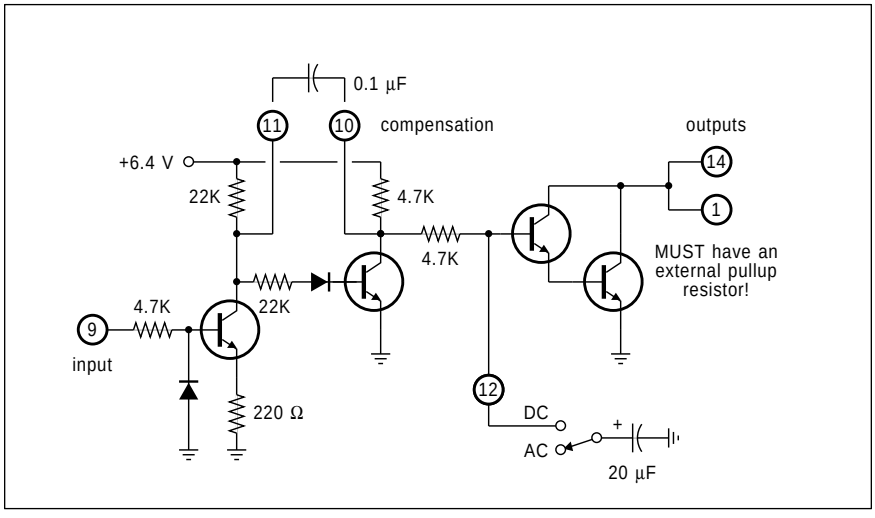


Fig. 5 – The ULN 2429 detector turns on with a square wave input greater than 1.2 volts peak-to-peak, and stays off otherwise. The filter capacitor can select either an AC or a DC output.

Don Lancaster's

Hardware Hacker

March, 1988

Understanding Posistors
More on superconductors
Monitors for the Apple IIgs
New video integrated circuits
IBM to Apple communications

I have found two more places to get information on those new superconductor developments we looked at last month. Check into the *Materials Research Society*. These folks now have videotapes and superconductor conference proceedings available, some that sell for as little as $15 or so.

While this next item is certainly not hacker priced at $750 per year, see if you can not con someone else into subscribing to that brand new *Superconductors Update Package* from *Chemical Abstracts*. Which is probably the ultimate source for all current superconductor info.

You'll find a story on page 177 of the October issue of EDN that gives you more uses and ideas for all those digital EEPOTs that we looked at two columns ago.

If you have any electronic high tech design that might in any way involve home furnishings, textiles, or clothing, there are prototype grants worth up to $10,000 now available through the *Innovative Design Fund*. Contact them directly for all of the rules and whatever.

We'll repeat our usual reminder that this is your column and you can get technical help per that end box. Our big goodie this month involves some new and reasonably priced hacker video integrated circuits.

But first . . .

Understanding Posistors

A *Posistor* is one trade name for a non-linear resistor whose resistance changes with temperature in a very unusual way. As figure one shows us, the resistance at first *decreases* gradually with increasing temperature up to a certain point called the *critical temperature*. Above that point, the resistance will instead dramatically *increase* with temperature.

These devices are available in a wide variety of sizes having various critical temperatures. Posistors are usually made from barium titinate that has been doped with strontium to adjust the critical temperature. Like most resistors, these are bipolar devices that will conduct equally well in either current direction.

Another name for these is a *PTC Switching Thermistor*. A pair of the primary sources of all these products do include *Murata-Erie* and *Midwest Components*. To get started with any of these, do check out Murata-Erie's new short form catalog 61-05 or else the Midwest catalog on Thermistors, Thermal Switches, and Varistors.

Despite their very low cost, their simple circuitry, and all their mind-blowing uses, posistors do not seem to have aroused much hacker interest to date. Yet, they are very interesting components that are quite easy to experiment with.

So what good are Posistors?

There are several basic ways of using a Posistor. If you apply a fixed voltage, your posistor will rapidly warm up to its transition temperature and will remain at that temperature. Thus, you have an all solid state and single piece *temperature regulator*.

Unlike a thermostat, there is no mechanical hysteresis nor any dead band present, and the switching can be exactly repeated.

And, unlike the thermistors and thermocouples, the highly non-linear resistance change forms a sudden and well defined switching point. On the other hand, that critical temperature is a fixed property of the posistor, so you cannot adjust it like you could a more traditional controller.

If you instead provide an input current, you end up with a *time delay* circuit, for the posistor will slowly heat up towards its critical temperature and then will effectively switch itself off. The time delay depends on both the current and the amount of heatsinking present.

If you place a load in series with your Posistor, you can build up an *overload protector* circuit. Whenever the load attempts to draw too much current or if the posistor overheats, the posistor will go into a very high resistance state, thus protecting the load from damage.

If the posistor isn't quite powerful enough, you can "amplify" its output suitably with a relay or else a triac. A companion heaters can also be used to control larger thermal loads.

Let us quickly look at some real world uses: A flat panel heater may be combined with a posistor so as to automatically heat up a liquid crystal display any time your ambient temperature gets down too low. A posistor can be used as an air flow detector by arranging things so moving air cools the posistor below its critical temperature, while lack of enough air flow will exceed the critical temperature.

A posistor placed in series with the starting winding of any motor will power the starting winding for only several seconds until the posistor can overheat and limit the current to a low value. This can replace the bulky and unreliable centrifugal switches used in many induction motors.

Alternately, a different posistor in series with the main motor winding will protect that winding from any mechanical or input overload. If the current gets too high, the posistor overheats, and then limits the current. Resetting is automatic and will take place within a few seconds after the overload stops.

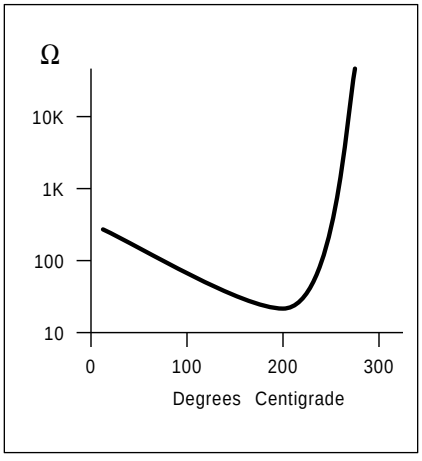


Fig. 1 – A typical resistance versus temperature curve for a posistor. If you exceed the critical temperature, the resistance sharply increases and the current dramatically drops.

Various other safety circuits are also possible. These could include using a posistor to sense the temperature of a battery being charged, to protect hi-fi speaker systems, to prevent thermal runaway in an electronic circuit, to sense the liquid level in a tank, or for use as a freezing alarm in solar panels.

Some tv sets use degaussing coils, needed to prevent any stray magnetic fields from trashing the color convergence. A posistor put in series with a degaussing coil will let the coil run for only a few seconds when power is first applied.

I am now looking into the use of a posistor as a heater for a cheap *Kroy Kolor* fusion machine, and separately to control the glue pot on a thermal binding machine.

It does look like the simplicity of a posistor gets traded off against the inability for adjustment over a wide temperature range.

Tellyawhat. For this month's contest, just dream up an unusual use for a posistor. Paper design are fine. The best twenty entries will receive a free book, while the best one of all gets an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two.

As usual, send your entries to me per the end box and *not* to the *Radio-Electronics* editorial offices.

Apple IIgs Monitors

Many help line callers seem to be after alternates to the stock linear RGB monitor as used with the IIgs.

The stock Apple video monitor is exceptionally sharp and works very well. On the other hand, it does cost $500, is strictly limited to the linear RGB systems, lacks a handle, and has video noise problems for any night people using very low brightness and contrast settings.

We'll first note that you must use a linear RGB monitor to tap the full performance from your IIgs. Those digital, or "TTL" color monitors common to IBM simply will not do.

Buying an unseen monitor on price alone is insane. So, rule number one is to not buy any monitor unless you can see *exactly* how it will look when running your actual programs.

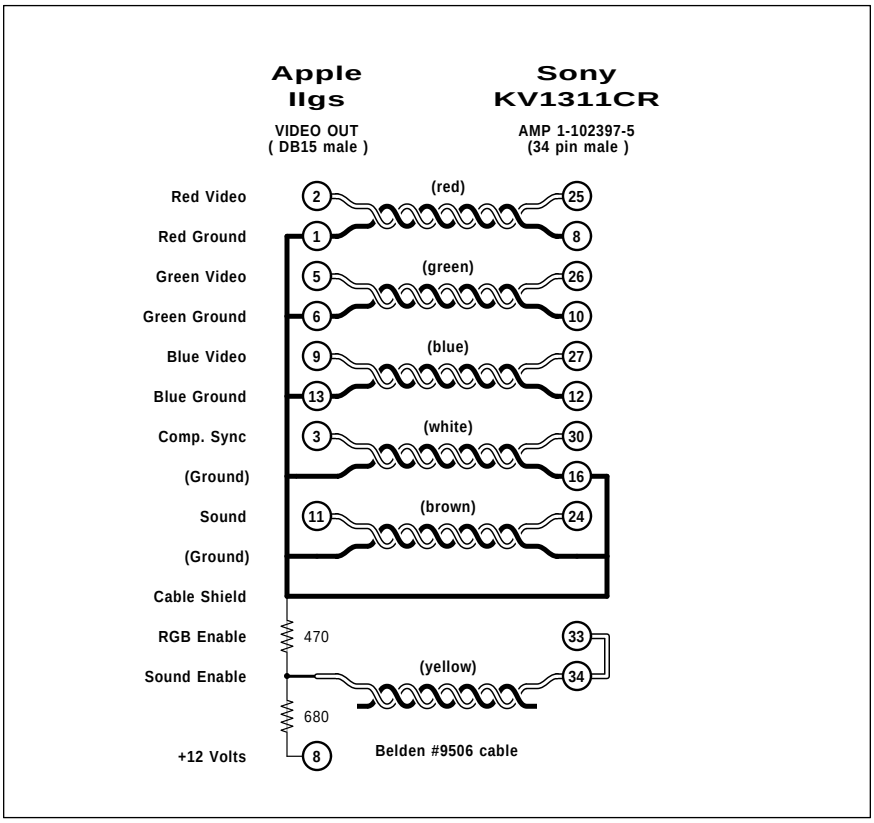


Fig. 2 – An interface cable to go between the Apple IIgs computer and the Sony KV-1311-CR linear RGB monitor/receiver.

Several helpline callers have asked about using the *Amiga* color monitor. Apparently this can be done, but only with some circuit modifications. My spies report the blanking widths of the color channels on the IIgs are too narrow to suit the *Amiga*. Please let me know if you have a solution on this particular interface.

The real winner seems to the be the great *Sony* KV-1311-CR monitor receiver. The praise lavished on this machine by the helpline callers was enough for me to actually go out and buy one for review and test.

What you have here is a 13 inch and $390 street price do-everything machine. This is a television receiver with 196 channels of off-the-air and cable capability, including a handy remote control. On the side is a fancy panel that has inputs for composite video, digital RGB, linear RGB, for audio, and even for teletext! Outputs include video, audio, VCR editing, and hi-fi multiplexed sound.

A special cable is needed to interface the DB15 connector on the IIgs to the 34 pin DIP header connector on your monitor receiver. Figure two shows you a schematic for this cable. You can also get these for $20 from the folks at *Redmond Cable*.

If you use the ready-to-go cable, be very careful to plug it in correctly. To keep the cost down, the connector is neither keyed nor idiot-proofed.

So how good is it?

The picture quality and color is every bit as good as the stock Apple monitor. But, since there are only 192 or 200 scan lines on the IIgs video, the 13 inch display tends to break up characters into individual dot lines. Thus, I feel the original monitor has a higher *perceived* character readability, that is particularly noticable when word processing.

On the other hand, 13 inches is often far too small to be pleasant for such activities as group VCR watching. So, I guess one problem with the KV1311-CR monitor is that the screen is both too big and too small.

By the way, this is strictly a NTSC set with the usual 15735 Hertz horizontal scanning. It is not at all suited for EGA or other uses that require a higher scanning rate.

Rumor has it that the low street price is partly caused by this being a

discontinued model, and that something better is now in the works. But something better is nearly always in the works. And probably much more expensive as well.

One very big warning: One person bought this for his IIc and tried using that composite NTSC (Never The Same Color) video input. He was appalled when he found all his 80 column text was hopelessly smeared.

There simply is no color monitor available anywhere that can attractively display 80 column text from a NTSC coded composite color video input. The reason, of course, is that there is not nearly enough bandwidth available in the NTSC encoding to allow display of more than 45 or so characters maximum across the video screen. This is why you go RGB in the first place.

So, yes you can use this monitor receiver with a IIc or a IIe. But your 80 column text will only be legible and pleasant when you have added an a third-party RGB card.

The small speaker present in the KV-1311-CR does sound considerably better than the tiny Apple speaker, but it is not in the least suitable for serious music synthesis use. You can take an audio output off the earphone jack for further amplification and/or better speakers.

It is nice to have the real volume control handy, compared to the front panel firmware setting. A pair of snap-on feet allow you to angle the display for monitor use or to flatten it for tv watching.

There's also no handle, a major defect that this monitor receiver does share with the original Apple unit. The center of gravity of both of the monitors is also in a very unexpected place, making either of them very easy to drop.

New Video Chips

I've just gotten word on two new *Maxim* chips that will have all sorts of hacker video uses. These are so new that I do not even have all the pinouts yet, but here goes . . .

Figure three shows you the new MAX455, a single chip $10, multiplexing video amplifier. What this jewel does is let you select one of eight video inputs and route them to a driver amplifier that can directly drive a 75 ohm cable. That channel selection is done by inputing a binary one-of-eight code. These channel select lines can be any length at all without serious problems.

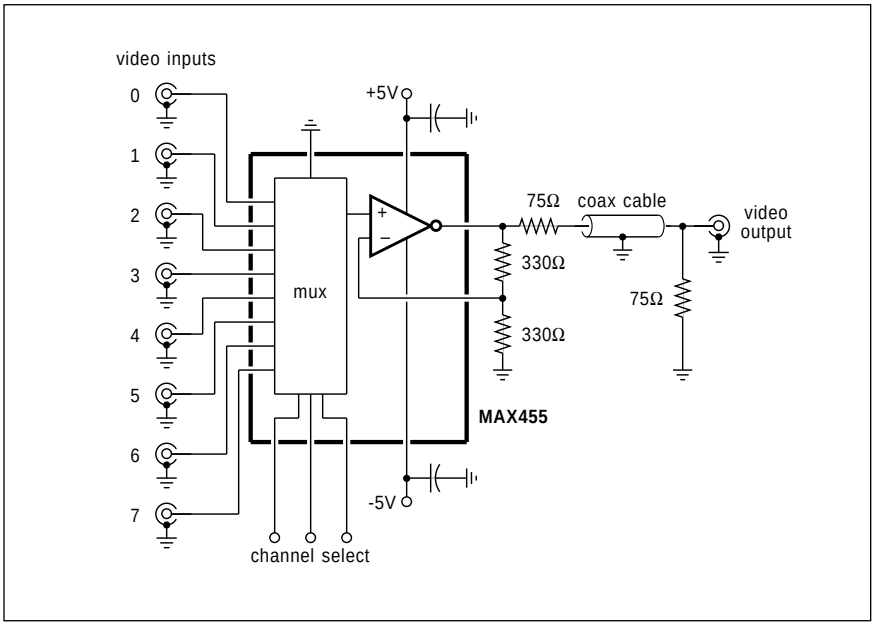


Fig. 3 – An eight position, single chip video selector and driver.

Channel isolation can be as high as 70 decibels. This borders on broadcast quality. Circuits of two and four input channels are also offered.

One obvious use would be as a home video control center. Inputs could come from your tv set, cable, VCR, and such. The outputs could be routed any way you like.

Maxim has also made the output video driver separately available as the MAX452. Cost is around $3, and it can easily drive long lengths of 75 ohm coax. The bandwidth can be as high as 50 megahertz.

One obvious use would be to drive several distant montors from a single personal computer.

Another warning: Despite their apparent power and simplicity, these are strictly advanced hacker components. You absolutely MUST use double sided printed circuit layouts with large ground plane areas. The shielding and guarding of inputs and outputs is manditory. A good oscilloscope is an absolute must. High quality decoupling capacitors MUST be used directly at the supply pins.

In short, any wide bandwidth video circuit will only work properly if you treat it with the proper respect.

Exchanging Text Files Between Apple and IBM

You can exchange text files from most any computer to most any other

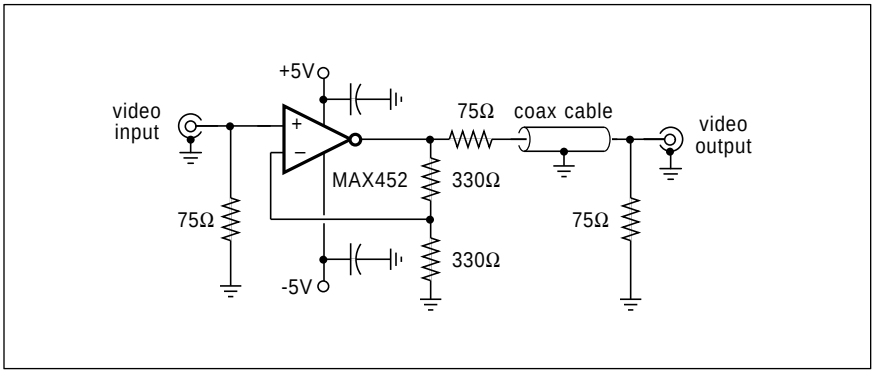


Fig. 4 – The video driver is separately available as the MAX452.

by using serial communication ports and then sending the characters from one machine to another.

Figure five shows you a simple adaptor that I built to let you get between an IBM PC and an Apple IIc, IIe, or IIgs. You build this adaptor from $5 worth of *Radio Shack* parts. It plugs directly into the COM-1 port of the IBM or clone machine.

Be sure to use two *female* DB25 connectors. A pair of soldered #12 wire loops can be used to hold the connectors together.

At the IBM end, you need a card that will give you the COM-1 serial interface. You also usually will need some sort of a telecommunications software package. I use *PC-Talk*.

On a IIe, I prefer using ProDOS *Applewriter* v2.0 or v2.1. This lets you send, receive, or edit your text, all within one single program. To receive, you use the [Q]-I command. To transmit, you use [P]-NP. An ordinary *printer cable*, such as might be used between the Apple IIe and an *Imagewriter I*, is used between the IIe and the adaptor.

It is very important that both ends are speaking the same data rate and format. A good starting point is 1200 baud, no parity, and two stop bits. You can speed things up later after your comm process is working.

Note particularly the treatment of pins 4 and 5. Their COM1 port uses these CTS and RTS auxiliary handshake signals, but Apple does not. Do watch this detail carefully.

Should you elect to use a comm program on the IIe end, you should also cross pins 2 to 3, 3 to 2, pins 6 to 20, and 20 to 6.

Thoughts on Tech Research

First and foremost, subscribe to or at least read as many possible trade journals as you can. I personally subscribe to over 300 magazines. So many times, you will find useful and profitable information in areas where you least expect to find it.

Secondly, get throughly familiar with a large technical library. One key reference called *Uhlrichts Periodicals Dictionary*. This shows you all the trade journals available in all fields and how to get them.

One obscure technical library tip: Practically all of the references will send you *backward* through time, and thus aren't that useful in fast breaking fields. But there is a reference called the *Science Citations Index* that, believe it or not, can move you *forward* through time.

How does it work? Every time a paper is referenced, that newer paper is listed. Just about any field has its early horses mouth source documents. For instance, anything competent written on active filters *must* reference *Sallen and Key*.

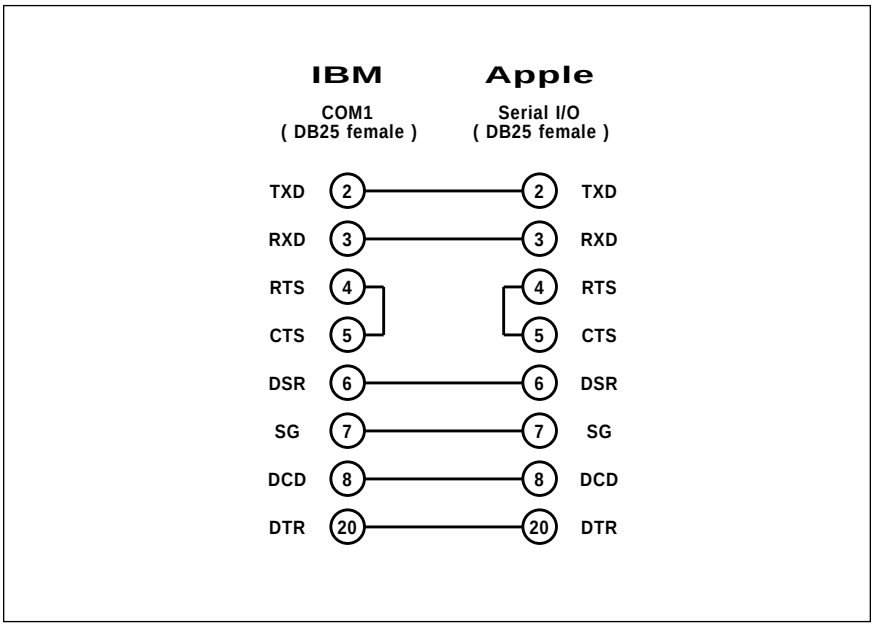


Fig. 5 – An interface for Apple to IBM textfile exchanges.

This can start a tree, for as soon as you will find a newer referenced author, you can also chase him *up* through time. Much more on all this appears in my *Incredible Secret Money Machine* book.

The third way to research is with electronic data bases. As an example, *NTIS*, among their numerous other published searches, can send you a 208 entry annotated bibliography on laser optical gyroscopes if your order #PB84-852987CAI. The charges are around $50.

New Tech Literature

There's an interesting *RF/IF Signal Processing Handbook* available free *Mini-Circuits*. Among all their other products, they have some very low cost (99 cents!) and ultra wideband linear amplifiers available.

One possible source for oddball or discontinued integrated circuits is *Rochester Electronics*. Stock here is on a catch as catch can basis.

You might want to see if you can qualify for a free subscription to the *NASA Tech Briefs*. This new monthly magazine has all sorts of interesting ideas, some electronic, others just high tech. More often than not, their ideas "just barely miss", but with a little thinking and rework, there can be a gold mine here.

News and Views of Imagineering is a very interesting newsletter with lots of future oriented ideas in the computing, electronics, and all the related engineering fields.

There's also a publication called the *Payphone Exchange* if you are at all interested in the commercial pay telephone business. These days, most anyone can install their own private pay telephone just about anywhere.

Turning to my own products, I've now got a complete set of bound and autographed *Ask the Guru* reprints from my sister column that is over in *Computer Shopper* magazine. These mostly involve Apple II computing and desktop publishing, plus several hacker goodies not found elsewhere.

And, if you might be thinking of converting your hardware hacking into a source of nickels, be sure to check into my *Incredible Secret Money Machine* book. Write or call, and I'll be happy to send you more info on these and others.

Don Lancaster's

Hardware Hacker

April, 1988

Bar code information
Pressure transducer data
Low pressure pneumatics
Battery powered regulators
New video imaging devices

Our big news this month is the brand new *Optoelectronics and Image Sensors Data Book* you can get from *Texas Instruments*. Inside it you will find the details on two remarkable chips, the TC240 and TC241.

These are both solid-state image sensors intended for use with video cameras and such, having a total of 367,952 photo elements, arranged in a 754 x 488 format.

Incredibly, the TC240 also includes a set of three built-in color filters so that one single device and one simple lens is all you need for full resolution red, blue, and green "RGB" color outputs. This is done by actually placing all of the individual filters precisely above each light sensing element.

If you aren't into using color, the TC241 is a similar chip intended for monochrome use, sans filters.

And, yes, they are both available. So much for all the good news. The bad news is that these are not yet hacker priced. These sensors list at $375 for monochrome and $405 in full color. And another five custom chips are needed to convert your sensor into a "real" camera.

On the other hand, these devices are available today, and the prices are certain to drop in the future. So now is a good time to begin studying high resolution CCD sensors.

Let's move on to one of my all time favorites . . .

My Favorite Surplus Part

It's been on the surplus market for at least ten years now, and virtually no one has ever picked up on this incredible hacker opportunity. It is called an automotive TCS valve, and they may be bought for as little as *thirty cents* (!) from *Jerryco*, besides being available in singles for $1 to $3 each from just about any other surplus house.

Not to mention the fact that these are now available by the barrel full at your local junk yard. Their original manufacturer does seem to be *Carter Carburetor*.

The TCS stands for *Transmission Controlled Spark*. Which are also called SCS valves, short for *Speed Controlled Spark*. Their original use was as a pollution control to prevent vacuum advance either in low gears or at low speeds.

Figure one shows you a typical valve. What you have got here is a three-way pneumatic control valve that can interface beautifully with most any microcomputer or other controller circuit. Do nothing, and the side pipe exhausts to ambient air by way of a filter at the rear. Apply +12 volts at 200 mils and the front pipe gets connected to the side pipe.

While it was intended for use as a vacuum valve, you can use it backwards with air pressures as high as 10 PSI. You can even run water through it, if you plug up the exhaust vent with epoxy.

Low pressure air in the 4 to 6 PSI range gives you all sorts of robotic and hacker opportunities. You can use a large aquarium pump with a simple accumulator made from a toilet bowl float, and a surplus regulator as a power source. Then you use these valves to activate various actuators under computer or manual control per your choice.

Unlike solenoids, air actuators are cheap, tough, powerful and offer a highly linear force. They also will amplify, since most of the muscle will come from the air pump, rather than from the electrical input. And unlike mechanisms, air lines can easily go around corners. This gets very handy for robotic elbows.

What about the actuators? Figure two should give you some ideas. One thing I have found out about using low pressure air is that you absolutely, positively must *never have a seal that moves!*. If the seal is a good one, then all your force will be spent overcoming friction. If the seal is not a good one, then all your air goes bye bye around the seal and is gone forever.

So, your best bet in actuators is to use balloons, rolling diaphrams, or bellows actuators of some type or another, since none of these have any seals that move. Old toys at a yard sale are often an excellent source of actuator ideas.

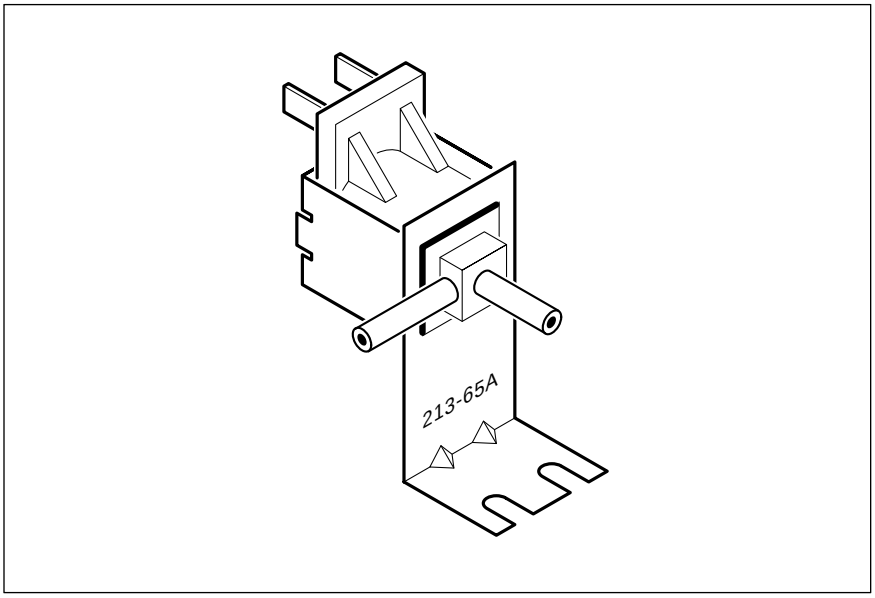


Fig. 1 – 3-Way automotive TCS valves are available surplus for as little as thirty cents each! They are ideal for robotics and for most other low pressure pneumatic hacking applications.

By the way, if you ever do need a static seal, a plain old "O" ring is the only way to go. The "O" rings nearly always work like a champ. Unless you do happen to freeze one up on a poorly designed rocket seal.

Some other sources I have found handy when hacking low pressure pneumatics: Check out *Hygenic* for low cost tubing and rubber sheeting, *Value Plastics* for connectors, and *C & H Sales* for regulators. You might also check out the *Clippard* people for real miniature air components, but these are expensive.

Another "must have" reference for low pressure pneumatics work is the superb catalog from the *Player Piano Company*. Check it out.

You'll get the best results in the 4 to 6 PSI range. Less than this and you don't get enough power. More than this and you get into seal and leakage problems that get nasty quick.

Figure three shows you a typical low pressure pneumatic system.

The accumulator is just a fairly large air tank that will hold your pressure constant during the pump cycles. Adjustable regulators, such as the one shown, will typically go for around $5 surplus.

The manifold is simply any way to distribute air to several valves and actuators. A bunch of "T" connectors could also be used. I once made a manifold by taking a foot length of heavy-wall rubber tubing, 3/4 inch o.d. by 1/2 inch i.d. and then putting a pinhole every place I wanted a TCS valve to go. Each valve snout was simply pressed through the tubing wall, giving an adequate seal.

One thing that many beginners to pneumatics often miss 1 three-way valves are usually essential. If you connect an air source directly to an actuator through a two-way (or SPST) valve, when you turn the valve off, the air stays stuck in the actuator and the actuator will stay extended.

Instead, the three-way valve action either lets you "fill" the actuator from the accumulator or else "empty" it to the ambient room air.

Tellyawhatweregonnado. For this month's contest, just come up with a paper design that uses these valves for economical low pressure control of gases or liquids. To get you started thinking, how about an automatic bartending/drink mixing machine? Or some sort of an aide for the handicapped? Or a device to convert any piano into a player piano? At any rate, there will be a free copy of my *Incredible Secret Money Machine* to the top twenty entries, and one all expense paid (FOB Thatcher, AZ) *tin-aja quest* for two to the best entry of all. Fair enough?

Info on Bar Codes

The bar codes, of course, are now popping up just about everywhere, and there are all sorts of nickels to be made reading and entering codes, printing labels, or offering label software for sale to others.

While there are several different "standard" bar codes, far and away the most popular one is called the *Uniform Product Code*. An outfit named the *UPC Council* will be glad to sell you a complete set of the UPC standards for $30.

If enough of you are interested, we might go further into just what these standards are and how to use them in some future column. I always like to work directly from the copy of an actual standard, rather than using any third-party information. There are fewer rude suprises that way.

Meanwhile, there are several other bar code resources you might like to pick up on. One group is called the *AIM*, otherwise called the *Association of Identification Manufacturers*. The membership list is particularly useful for pinning down bar code sources.

Two free trade journals are also now available for all you bar code enthuasists. One of these is called *Automatic I.D. News*, while the other one is the new *Identification Journal*. The latter people also do publish the related *Marking Industry*.

Battery Powered Regulators

There is often a real dilemma in any portable electronic equipment, particularly all the ultra low power hacker stuff. Many of the integrated circuits require a finely regulated supply that is very close to +5 volts DC. On the other hand, you often would like to run off a penlight cell or two, or off a nine volt "transistor" radio battery.

A very innovative Silicon Valley integrated circuit house has come to the rescue. The *Maxim* people have some outstanding low power regulator circuits at very low prices. They also do have a *Power Supply Circuits Handbook* that you might like to get, as well as a new monthly mailing that is titled the *Maxim Design News*.

Figures four and five give you two examples of what you could do with their components. Figure four is a switching mode regulator that steps two AA cells up to a solid and regulated five volts. The intended output power is ten mils or less, for which you might get 80 hours or so of operation. The integrated circuit by itself needs 100 microamperes off the battery.

Figure five shows you a classic linear regulator that drops +9 volts down to the needed +5. Linear regulators are normally considerably less efficient than switching ones. At

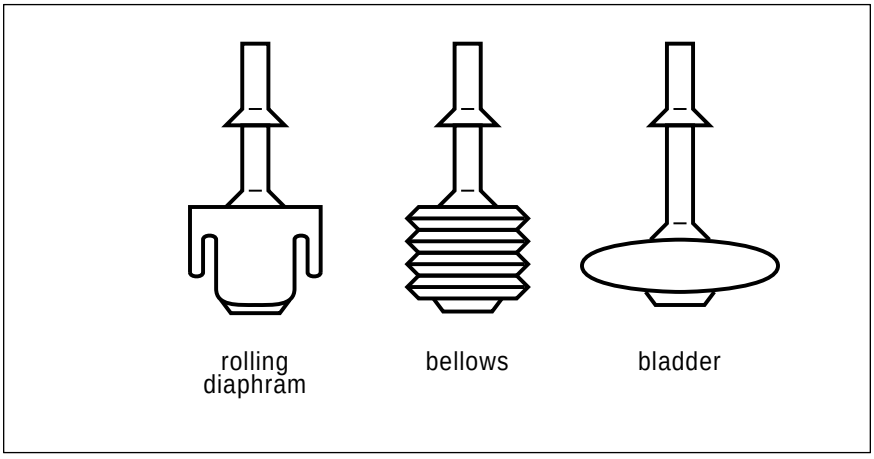


Fig. 2 – The formost rule of low pressure hacker pneumatics is this: NEVER have any seal that moves! Here are some actuator ideas to get you started.

ten mils load, you will get around 55 hours of operation.

But this linear regulator has one exceptional feature 1 It only needs a mere 5 microamperes to operate. So, for very low load currents, this MAX 666 might actually give you a longer battery life.

Let's think about where we could go with an ultra efficient, ultra low voltage regulator. One quite obvious use is solar power, where a few series connected 0.6 volt cells could be up-converted to useful voltage levels.

What about this: A super efficient, three volt output switching and up-converting regulator that might be powered from a riciculously low input voltage, say 0.4 volts or so. Just snap one of these onto the top cell of your flashlight, and you can utterly and completely flatten your flashlight cells clear down to zilch, all of the while maintaining a constant lamp output brightness.

The SCSI Interface

SCSI stands for *Small Computer Standard Interface*. This is a popular and standard way of connecting hard disks and any streaming tape backup systems to personal computers. Since that SCSI, or "scuzzy", interface is quite good at the rapid transfer of large amounts of data, you'll shortly see its use for such things as laser printers, image processing, document scanners, CD disks, and in high end graphics workstations. With dropping prices, you'll see more SCSI use.

Much of the new interest in this standard centers on the new SCSI interface in the *Macintosh* lines by *Apple Computer*. SCSI interfaces for the Apple IIc, IIe, and IIgs are also now available.

The SCSI interface is fully documented in *ANSC X3T9.2 SCSI Specification*, now available for $20 from *CBEMA*. An ongoing tutorial on this standard began in issue #22 of *The Computer Journal*.

For magic chips that make SCSI go, check into the *WD33C92/3* from *Western Digital*. They also have lots of data sheets, ap notes, and listings available on request.

We can delve into this a lot further if enough of you hardware hackers are interested.

New Pressure Transducers

The pricing of new silicon pressure transducers does continue to drop ridiculously, and I am now working up some sample circuits for you. But, to get you started, the *Nova Sensor* people recently had an $11 in quantity one sale on their new NPS-100 pressure sensors. This beauty comes in a six pin mini-DIP. It is rated 0-15 PSI, but it will require an external op-amp for most serious hacker uses.

You might also like to get a copy of the new *SenSym Pressure Sensor Handbook*. There is a wealth of good design information here on exactly what pressure sensing is all about and how to go about doing it. A pressure slide rule and a top notch series of application notes are also included.

Piezoelectricity

Piezoelectricity is the property of certain substances which produce a voltage when they are stressed, and conversely, to stretch when they have voltage applied to them. Two very old examples of piezoelectric components are the quartz crystals used for frequency standards, and those Rochelle Salt crystals long ago used for phonograph cartridges and crystal microphones. A few years back, new piezoelectric materials came along involving man-made crystals called PZT and PZBT. These are used in such things as gas pilot ignitors, and sonar transducers.

One useful resource on all this is the *Piezo Technology: Data for Designers*, a 40 page manual available from *Vernitron*.

But, there is now a brand new piezoelectric ball game. A magic thin film plastic is now available from *Penwalt* called *Kynar Piezo Film*. As it is available in thin sheets, many new applications can now be found for piezoelectricity.

For instance, you can now build piezoelectric fans which have zero moving parts except for their vibrating plastic blades. These can be made small enough to deliver the cooling air exactly where it is needed, and do so both reliably and quietly.

The piezo film apparently is not as sensitive as those older piezoelectric materials, but its form factor more than makes up for this. The film is also pyroelectric, which means it can also be used for applications such as infrared receivers and detectors. One possible application would be a low cost "hot spot" detector for firemen who need to look inside the walls on a post-fire overhaul.

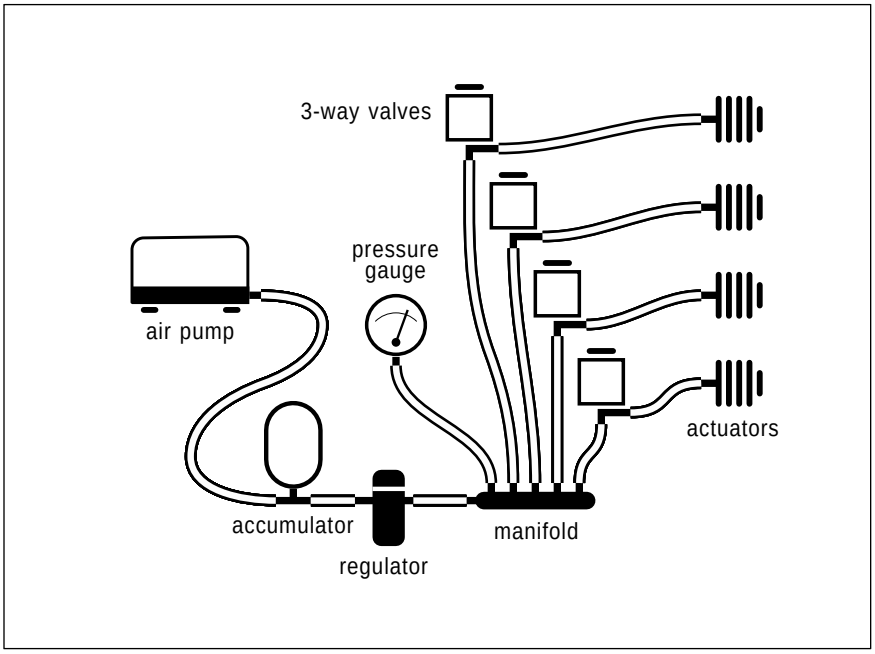


Fig. 3 – A typical low pressure air system. Note that three-way valves MUST be used; otherwise, the air will stay stuck in the tubing and all of the actuators will remain extended.

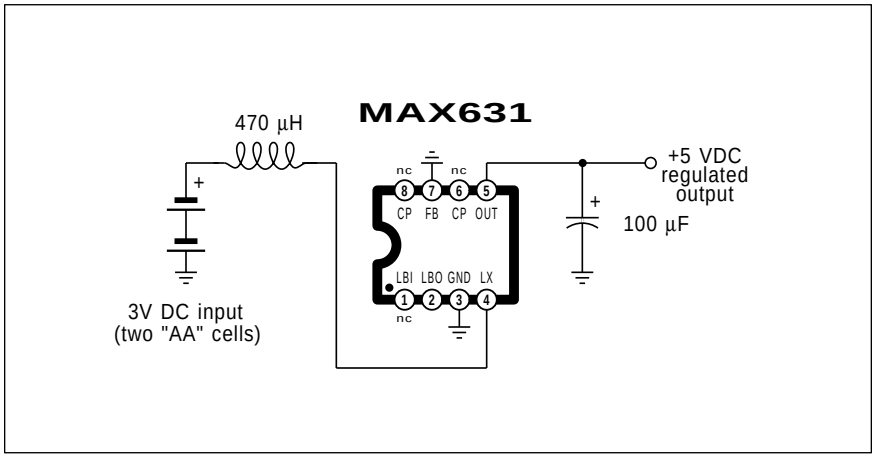


Fig. 4 – This simple switching regulator steps up two AA cells to give you a fixed +5 volt output at 10 Milliamperes. A pass transistor can be added for more output current.

You can get a tiny free sample by a letterhead request to Penwalt. They also have a $45 evaluation kit that does include full technical data, all of the needed connectors, and samples of all the various film types.

Several of the new uses for these piezo films sure are unique. They include pickoffs for very high quality violins, impact detectors for sports training dummies, large area transducers for sonar hydrophones, flame detectors, and even for use as cuddle sensors for child's toys.

Let me know what you come up on that's as good as these, for there are literally hundreds of possible construction projects that could be worked up by using this exciting new hacker transducer material.

New Tech Literature

There's a new and informative free *HeNe Laser Guide 2* available from the folks at *Melles Griot*. Besides the usual red color, they also now offer their helium-neon lasers in green and infrared. These are a tad pricey; for the best in surplus and other low cost lasers, you just may want to look into *Meredith Instruments* instead.

Also, be sure to check into that new *Standard IC Product Guide* from *Ferranti Semiconductors*. Included here are full details on such hacker IC oddments as special television test pattern chips, low noise preamps, telephone circuits, A/D and D/A stuff, video circuits, digital thermometers, and lots more.

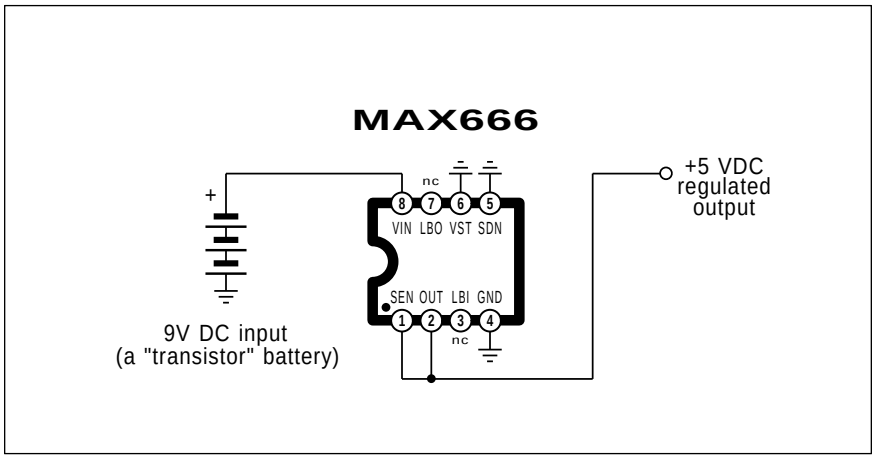


Fig. 5 – This linear regulator drops down a 9 volt battery to give you a fixed +5 volt output at up to 40 milliamperes. The standby current is a mere five microamperes.

A new *Integrated Circuits and Microcomputers* short form catalog is avilable from *Seimens*. Included here are remote control chips and infrared receivers, among some other gems.

Reticon has come up with a brand new and free *Image Sensing Products* handbook, while *Texas Instruments* has a new literature packet and an apnote on *CCD signal processing*.

Xilinix has a *Programmable Gate Array Design Handbook* out on the next step beyond those EPROMS and EPALS 1 entire gate arrays that you can electrically program by yourself. The price of these arrays are still very expensive, but they are bound to become great future hacker toys.

Standard Microsystems also has a new data book out on the dedicated integrated circuits used for data communications, video display systems, keyboard encoders, and such.

Harris Semiconductor has a new products guidebook on their digital and linear ic's. They do tend to be a bit pricey at times. And *Toshiba* has released a new MOS Memory data book with lots of good info in it on RAM, ROM, and EPROM products.

Advanced Linear Devices has a micropower 555 style timer that will run on as little as one volt of supply power. This one looks like a great hacker item.

The *Relay Specialties* people have an interesting free catalog that lists pretty near any relay from just about any source. There's no bargains here, just a very wide selection of first rate products at the usual list prices. Be sure to ask for a complete price list with your catalog request.

Precision Monolithics has a new 1987 data book on linear and data conversion integrated circuits. Their ap notes tend to be built into their data sheets, but there is a complete subject index. This is a great source of linear circuits and ideas.

Any of you hackers into robotics will be interested in the $9.95 *Nyliner* bearing evaluation kits from all those *Thomson Industries* folks.

Turning to my own products, for those of you that are interested in any Apple computing, there's my *Apple-Writer Cookbook*, the *Apple Assembly Cookbook*, *Enhancing your Apple IIe*, volumes I and II, and my *Ask the Guru* reprints.

Don Lancaster's

Hardware Hacker

May, 1987

The PostScript language
Telephone ring detectors
Toner cartridge reloading
Unique new A/D converter
Replacement semiconductors

I just got wind of a stunning new medium level hacker integrated circuit that should cheaply and elegantly solve a lot of sensing and analog interface problems for you. This chip is the new LTC1092A by *Linear Technology*. While I don't yet have a samples or complete data, some preliminary technical info did appear over in *Electronic Design* for December 10, 1987, on pages 47-50.

This little $12, 8-pin minidip gem is a single-piece 10-bit *low level* and high speed analog-to-digital converter. What it does *all by itself* is take a small analog signal sitting on a large or even a slowly varying offset voltage and convert it into an 0.1 percent accurate 0-1023 numeric value.

The LTC1092A is able to handle a serial interface with most any personal computer. It does seem to be especially good for talking through the Apple game ports.

Unlike previous A/D converters, this is a *floating point* unit that can have its maximum full scale value set anywhere from 150 millivolts (!) on up to 10 volts. Which will give you a mind-numbing dynamic range of nearly 97 decibels. That same chip can measure anything from a mere 150 microvolts up to 10 volts.

The potential hacker uses boggle the mind. One recent helpline caller wanted an to build an expanded scale voltmeter. Another asked for a way to accurately measure the charging voltage of a large industrial battery, by detecting the end of charge when the voltage starts to rise suddenly.

You are able to directly input such things as a "raw" strain gauge, pressure transducer, a thermocouple or other temperature sensor and in one step get a numeric result. No more instrument amplifiers, voltage references, critical pc layouts, precision resistors and all of the hassles that go with them.

And, yes, this one is fast enough for most any high quality audio use. You can even digitize 19 KHz audio at a 38 KHz sampling rate.

Operation could not be simpler. There are two supply pins that work from a single +5 or a +10 volt supply and ground. You do have two differential input pins along with a reference input that sets the full scale amplitude. A precision reference is not needed, since you can get this signal from the same source that is driving your sensor or whatever.

Those remaining three pins are all digital. You will find a clock input, a "start converting" input, and a serial output. Which should interface quite well with just about anything at all.

We'll be seeing lots more on this beauty here. Yes, there definitely will be one of our usual contests. To get a head start, just pick up some of the data sheets, samples, or ap notes, and see what you can come up with.

This is your column, and tech help is available per the help line in the ending box. Let's start off with a great business idea . . .

Toner Cartridge Reloading

Toner cartridges, such as those that are used in all of the *Canon* personal copiers, in *Hewlett-Packard* LaserJets or the *Apple* LaserWriters, cost as much as $124 each and are good for only 2500 or so copies.

Yet, with a very simple two minute operation, you can reload all of these empty cartridges three or more times with new toner at a cost as little as $7.50. At the same time, you might get better and blacker images, since the rest of that cartridge mechanism does not even begin to get up to its maximum blackness until well after its *second* reload, and since the refill toner materials are much blacker than the factory original.

If you now own one of these laser printers, you can dramatically reduce your operating costs and improve the quality of your output by doing your own refilling. If you do not, chances are others in your neighborhood will be glad to pay you as much as $24 for a local and custom refilling.

One good source of refill toner is *Lazer Products*, while a reliable and independent toner refill testing and reporting service is available through *Thompson and Thompson*. Note that refill toner must be exactly matched to its target cartridge. Copier toner will not work at all in a laser printer and vice versa.

Let us look at how you can refill a *Canon* CX cartridge. The details will vary with other systems. You can get your empty cartridges by accepting exchanges or else by putting an ad in

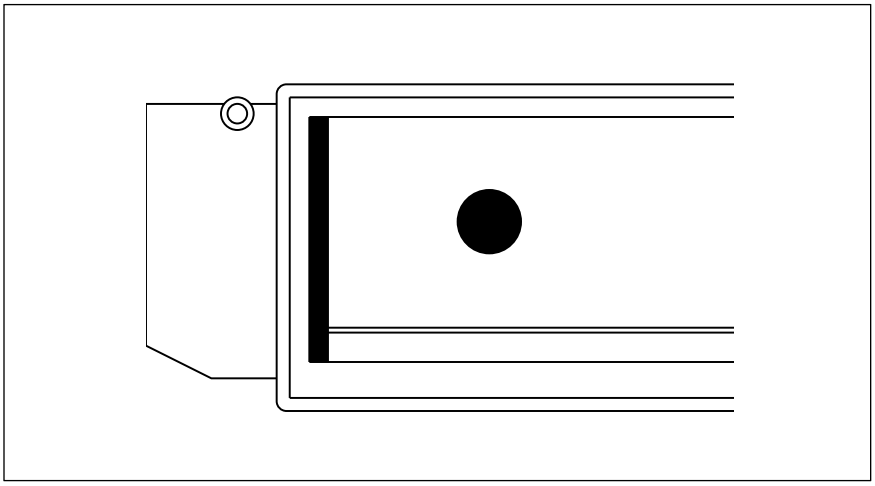


Fig. 1 – A Canon CX toner cartridge has to be modified before it can be refilled. First, remove the large cardboard label (not shown here) by lifting it up from each end. Then, drill a clean 1/2 inch hole in the fresh toner tank using a Vise Grip #3 Unibit. Carefully remove the chip.

your local paper. The current street price of empty but virgin cartridges is $5 in urban areas and $10 in small towns and rural areas.

In fact, there is never any point at all in *ever* buying a brand new CX cartridge. You might as well allow someone else condition the drum and get rid of all of the less-than-perfect factory toner for you.

There's usually no good reason to completely tear down a cartridge. All this does is introduce more problems than it solves. I will show you the "punch and go" method here, since this is far more cost effective. But, if you absolutely insist on tearing one apart, the magic tamperproof *Torx* bit is available as *EVCO* part #945B700 from *Jensen Tools*.

With the punch-and-go method, you have to drill two holes in your cartridge, as shown in figures one and two. The easiest way to make these holes is to use a special beastie called a #3 Vise Grip *Unibit*. This is a special conical drill that easily can drill thin and brittle materials without cracking. Use a very slow drilling speed and be very careful to remove all chips. If you drill upside down and slowly, you should end up with only one continuous chip.

One 1/2 inch hole is placed in the toner filling tank, and a second 1/4 inch one is placed in the spent toner holding tank as shown.

The toner filling tank is reached by popping off the large cardboard label. Do this from the ends, and *not* from the sides. A pocket knife works fine.

Suitable tape, such as the metallic tape used in certain floppy disk write protect tabs, is used as a seal. It is of the utmost importance that your sealing tape is very aggressive.

To actually refill a cartridge, first open the holding tank and drain out the old toner. Do this outside and do avoid breathing the toner. Then, you reseal the holding tank. Next, use a plastic funnel to dump one bottle (typicaly 400 grams) of toner into the filling tank. Then reseal.

You follow this up with a stick-on label that holds the refilling history of the cartridge. Finally, replace the original cardboard label and clean the corona wire with the little green tool provided with the printer.

When you refill the cartridge, you should also replace the wiper pad that cleans the fusion rollers. These pads contain a small amount of a special silicon oil, so they must get replaced, rather than just cleaned or recycled.

Wiper pads are often included free when you order toner. Simply scrape the original pad out of its holder and peel and stick the new one in place.

Refilled cartridges must be hand carried. They slould not be shipped without adding an additional and specialized sealing strip. Thus, all of your cartridge reloading is best done as a custom local service.

It is also a highly good idea to use *Pixie Dust* or some other lubricating drum conditioner. Put the Pixie Dust in an old sock and *lightly* dust your green drum when you first begin use of a cartridge, and for every refill that you do afterwards.

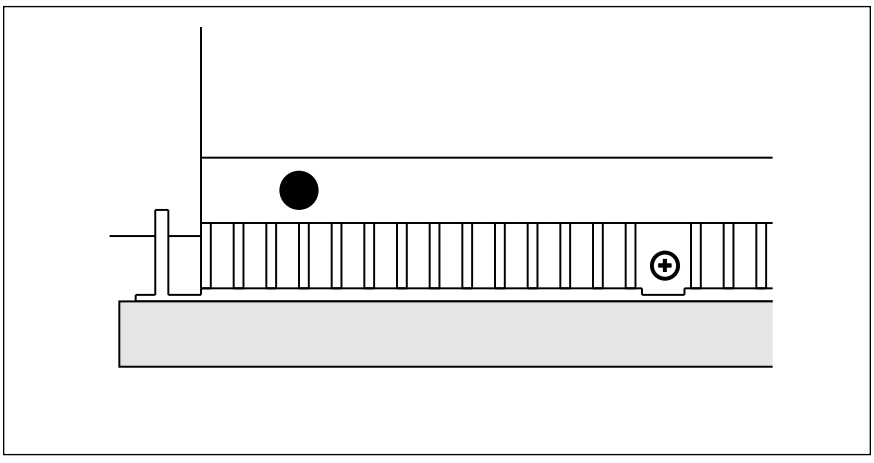


Fig. 2 – Continue modifying your CX cartridge by drilling this 1/4 inch hole in the spent toner holding tank underneath the cartridge. When you are done reloading, seal up both holes with a very aggressive tape. Be sure to replace the cardboard label and the fuser wiper pad after refilling. Finally, do a light dusting of the drum with Pixie Dust or another drum conditioner.

Some ongoing details on cartridge reloading and refill ecomonics appear in my *Ask The Guru* reprints, while a step-by-step demonstration also got included as a small part of my *Introduction to Postscript* video.

Speaking of which . . .

Learning PostScript

Several helpline callers have now complimented me on the technical illustrations for this column and have wondered exactly who the artist was. Well, the artist is neither a he or a she. It is an it.

Everything that you see here, including all the text, the captions, all graphics, and all the tech illustrations was produced camera-ready by using nothing but the *AppleWriter* word processor on a IIe, and printing on a *LaserWriter Plus*. This is all made possible by the unique graphics and typesetting language that is known as *PostScript*, from Adobe Systems.

PostScript is an industry standard page description language that is also making strong bids to become a screen description standard, a fax standard, a newer BBS graphics interchange standard, a signmaking and engraving standard, and even a new printed circuit layout standard.

The good news about PostScript is that you can simply and quickly use any old word processor on any old computer and create graphics that can meet and often ridiculously exceed the finest graphics output as available from the most expensive custom programs for the fanciest of computers.

The bad news is that PostScript will only work on premium printers and typesetters that have PostScript capabilities already built into them. Current examples now do include the *Apple* LaserWriter and the LaserWriter Plus printers and the *Linotron* 100, 200, and 300 phototypesetters. These are still a tad expensive.

Some major advantages of PostScript include *device independence*, which means that the very same code and very same textfile can be used for 300 DPI personal laser printing or for 2560 DPI commercial typesetting.

Fig. 3 – An ordinary word processor is all that is needed with the PostScript language to create graphics that look this good. These examples show you several of PostScript's powerful curve tracing and cubic spline abilities. Any personal computer can be used as a host machine.

PostScript fonts can be set to any size, ranging from two points up to 40,000 points or even larger, and may be independently rotated, scaled in size, translated, or have any of hundreds of other specialized treatments applied to them.

Thousands of different PostScript fonts are now available, and each of these individual fonts can be shown on the final page in a nearly infinite number of exciting variations.

Full pages of text and graphics can now be freely intermixed in most any combination, in any direction, and in most any manner.

PostScript is similar to its *Forth* second cousin three times removed and five times disowned in that it is a *threaded* and an *extensible* language. Which means that you can now add any- thing you like to the language anytime, thus creating your very own custom and reusable code.

One of the most unique features of PostScript is its internal inclusion of a powerful means of drawing smooth curves that go by the name of *cubic splines*. Figure three shows a few of the awesome things you can do with PostScript's cubic spline capabilities.

Yes, PostScript is incredibly easy to learn. In fact, PostScript can easily become downright addictive. Off-the-street students in my beginning PostScript courses are doing all their own superb custom letterheads, ads, forms, business cards, badges, line art, decals, and bumperstickers after as little as three hours of instruction.

Those of you hackers that have been following me over in *Computer Shopper* know that I am into PostScript in a very big way. You can get started with all this on your own by calling up our free PostScript voice helpline at (602) 428-4073; by calling one of the free PostScript BBS bulletin board systems at (713) 688-1779 or (707) 852-2390; by getting a free subscription to that *Colophon* magazine from *Adobe Systems*; or else by picking up any of my other Postscript goodies that are mentioned at the end of this column.

Replacement Consumer Semiconductors

While nearly all the transistors and integrated circuits do get built in the same way by the same people, there

are several different ways that these devices are sold. If you are a builder of, say, television sets, you will buy these directly in huge quantity lots, already custom numbered for you per your own internal needs.

If you are a hacker, designer, or a developer, you will instead buy your standard numbered parts from any of the usual industrial or new age distributors, including many of our fine *Radio-Electronics* advertisers.

Finally, you will find yet a third distribution channel. This one is intended specifically for technical training, for maintainence services, and for consumer electronics repair. Here, small quantities of the house numbered chips are all stocked specifically for service and warranty uses.

As a hacker, you wll want to tune into both the standard numbered parts sources as well as those service and warranty replacement sources. More often than not, what you get from one distribution channel will be totally unheard of by the other.

Two of those leading sources of replacement semiconductors are the *ECG* people and the competing folks over at *NTE*. Both sources do have fat and low cost technical directories that list and then willcross reference zillions of house part numbers. The package details, pinouts, and limited technical data are also included.

No hacker can afford to be without current copies of these.

Telephone Ring Detectors

A typical home telephone line will normally consist of a 48 volt DC supply that drops to half that when you are off-hook. This DC supply then gets amplitude modulated to provide voice or data communications.

The ringing is separately done by superimposing a strong AC *ringing signal*. This is typically a sinewave of 40 to 150 volts RMS at a frequency of 16 to 68 hertz.

Traditionally, the ringing voltage got capacitor coupled to a mechanical bell whose resonant frequency did match that of the ringing signal. On some of the older party lines, several different resonating frequencies got used for the bells. Each party could get selected by changing the frequency of the selected ring signal.

You might like to build your own ring detector, possibly as an aide for the deaf; for use as a modem or answering machine; for any automated computer communications; or simply as an outside, a remote, or a super-loud or a super-quiet way to decide when your phone is ringing.

One way to do this is with a plain old neon lamp. Take a NE-2 and put it in series with a 470K resistor and a 0.47 microfarad, 400 volt capacitor and hang it across the phone line. Or use a neon nightlight instead. Your neon lamp lights whenever the phone is ringing, and is out otherwise.

To provide a safety isolated ringing signal, just get a photoconductive cell or a phototransistor and tape it to the neon lamp. You then can input the photodetector into your whatever.

These days, though, you will find lots of simple, low cost, and rather sophisticated integrated circuits that you can use to detect the ringing and then directly drive a piezo transducer or else a small speaker.

Many of these are described in the new *Telecommunications Data Book* by *Texas Instruments*. Let's look at two different examples.

Figure four shows you a detect-only circuit that uses a TCM1520A to light a LED or else drive the input of a LED optocoupler. The output is a pulsed DC signal that is present when the phone is ringing.

Figure five will show you a detect-and-drive circuit that makes use of a TCM1532 to directly drive a piezo transducer, or else can let you transformer couple to a speaker or to an external and isolated amplifier.

To get a decent sounding ring, you really want to pick a pair of different frequencies and warble between them. Further, you'll want to match these frequencies to whatever you are driving. This is done automatically for you inside the chip. A number of different part numbers are available that will give you various ring frequencies and warble rates.

Note that this second circuit can also drive a LED, and the LED will even *appear* to light continuously on a ring. But remember that the actual waveform across the LED will be a complex audio signal that may need further treatment before final use.

There's other uses for these chips that do include burgular and process alarms, or even low power and direct line-operated power supplies. See the data book for more details.

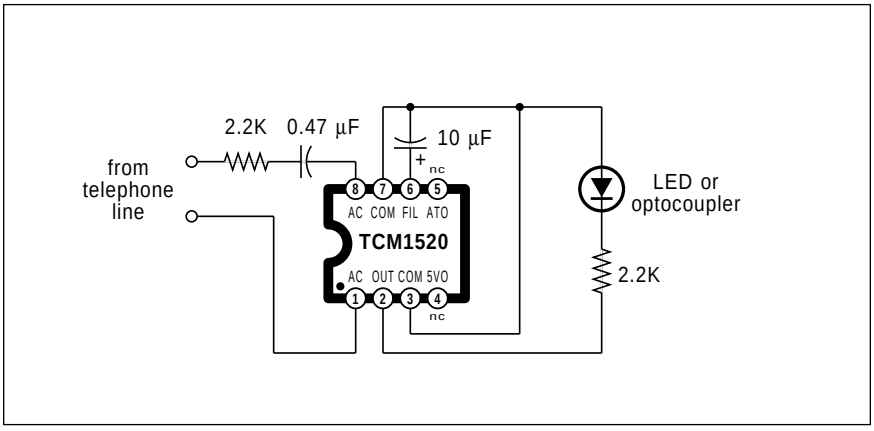


Fig. 4 – This telephone ring detector might be used to light a LED or to power a LED optocoupler to create an isolated "the phone is ringing" digital signal.

Finding Tiny Hardware

Obvious places to look for unusual hardware in very small sizes are your local hobby store, jeweler's supply houses, and in the *Model Railroader* magazine. Who, by the way, do have some of the most outstanding tech writing to be found anywhere. Many of their advertisers do provide small hardware, along with plastic, wood, and metal raw material stocks. They also do carry many of the miniature tools needed to work with these smaller materials.

One source of miniature taps, nuts, and screws is *J. I. Morris*. The very *largest* screw size they stock is 2-56, and they go down to 0000-160. These are available in both brass and in stainless steel. Typical pricing is $10 per gross in brass, more for stainless.

Low Cost Parts Quick

A helpline caller recently needed great heaping bunches of LED lamps, cheaply and in a hurry. Two obvious hacker sources for this would be to use *Jameco* or *Mouser Electronics*.

But 1 and *only* if you are talking *big* quantities 1 there is one far better and far cheaper source. Just check out the distress and odd lot classified ads in the back of *Electronic News*. The prices on pretty near any mainstream electronic part listed here are unbelievably low.

Very few hackers have ever heard of this incredible parts source. Yet, all of the prices are very good, and the quality is usually first rate.

One little gotcha is that there is typically a $250 minimum order, or even worse yet, a $100 line item minimum. In the case of a 3 cent LED versus a 15 cent LED, though, your "breakeven" quantity would only be 660 pieces.

A second obvious limitation is that each transaction is a one-shot deal. You may never again get either the part or the price you are after.

Robotic Cow Contest

A *Radio-Electronics* Hardware hacker has a problem that you may be able to help solve, so we'll make it into this month' contest. I'll award the usual *Incredible Secret Money Machine* book to the best ten entries, and an all expense paid tinaja quest for two (FOB Thatcher, AZ) to the best overall entry.

The problem is to design a robotic cow. Rodeo is still a very big sport in many parts of this country. To train the cowboys and their roping horses for certain events, a robotic cow is needed. Especially if it is patient and totally cooperative.

The pseudocow has to travel along an 80 foot long linear track and must be able to rapidly change speed and direction, both under programmable and remote operator control. For as much as possible "found" or adapted materials are to be used. The budget is tight, say a $250 maximum, not including stock personal computers or standard R/C radio controllers.

To get you started in your thinking, could a garage door opener be of any help? How?

New Tech Literature

Newsletters are often a very high energy source of hacker ideas. One new one is known as *TecSpec*, and is quite strong on lasers and in optical communications. The coverage is all very hacker oriented. And the cost is only $1.50 per issue.

My favorite technical newsletter of all, though, is *Speleonics*, which will weigh in at a budget-breaking $6 per year. This one is written by and for spelunking cavers who have a technical bent. Topics of special interest include underground location finding, laser mapping, low frequency radio communications, geophysical exploration, and innovations in lighting and compasses.

The good people over at *Fairchild Semiconductor* just came out with a new free *Power Products Data Book*. This beauty includes several ap notes on switching power supplies and on the use of power MOSFET devices.

General Instruments has released a new short-form product portfolio. Here you will find sound generation integrated circuits, character generators, keyboard encoders, and even credit-card size memory devices.

There is a now new and free *Triac Applications* handbook you can get from the *Thomson Semiconductor* folks. While full of good ideas, this is poorly written and even worsely translated. To this day, the best book on power control semiconductors is the ancient *GE SCR Manual*. I'm not even sure this one is still in print, though. Please let me know if you know of reprint availability.

The *Mini-Circuits* people have a new how-to-use guide for their *MAR Drop-in Amplifiers*. These are a new series of very low cost and ultra high frequency transistor amplifier chips useable as high as 2 Gigahertz. One application area would be satellite tv.

Turning to my own products, if you want to know any more about the *PostScript* language we talked avout above, I do have scads of PostScript stuff for anyone from a rank beginner on up through certain testing, development, and a few leading edge advisory services for even the the most gonzo of advanced PostScript programmers and developers.

For beginners just getting started who do not yet have access to a PostScript printer, I would suggest my *Introduction to Postscript* video and Adobe's *Postscript Cookbook*. If you already own your PostScript printer, there's my *PostScript Show and Tell*, my *Postscript Technical Illustrations*, and my *PostScript BBS Stuff*, available for all of the major personal computers.

Write or call, and I will be most happy to send you a brochure on all of this and lots more, some free, and some not. Check it out.

As per usual, we have gathered the referenced *Names and Numbers* into the common directory at the rear of this volume. We'll end up with our usual reminder that your best calling times are weekdays, 8-5, *Mountain Standard Time.*

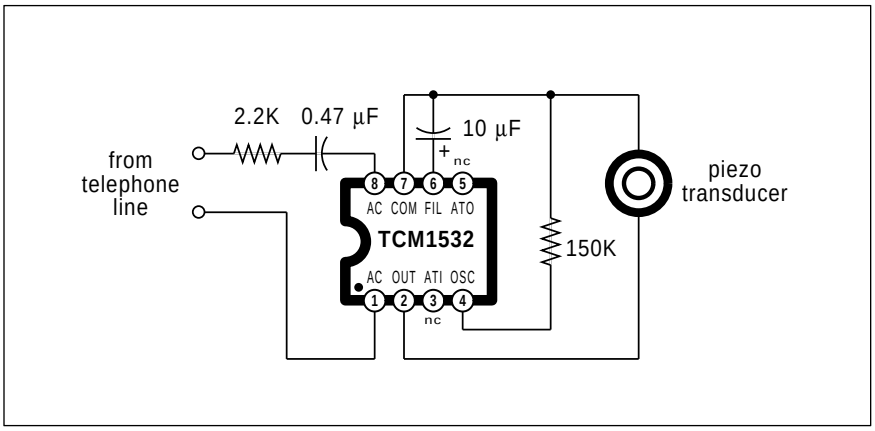


Fig. 5 – A combined ring detector and driver that directly powers a piezo transducer. Speakers or external amplifiers can be driven by transformer coupling. Note that all of the needed power is derived directly from the AC ring signal. Use a 400 volt input capacitor.

Don Lancaster's

Hardware Hacker

June, 1988

Finding parts sources
Perspective Transforms
More on superconductors
The RS-232 serial interface
Computer memory expansion

There does seem to be a lot of brand new sources for all the hacker superconducting samples and materials. A few of these are ridiculously overpriced while others are becoming real "best source" bargains.

That $8 superconducting sample from *Laboratory Specialists* would appear to be the low cost winner, but there is also a $25 package newly available through *National Superconductor* that will give you a much larger and more stable sample with pre-attached leads, along with the necessary super strength magnet.

Two of those higher priced superconductor sources include *Edmund Scientific* and *Fluoramics*. A low cost entry from *Heathkit* is also expected real soon now.

We will put our usual reminder here that this is your column and you can get technical help per that end box. Please also note the *Names and Numbers* section which can show you where to go for additional technical information on all of the products that get mentioned.

Let's start off with . . .

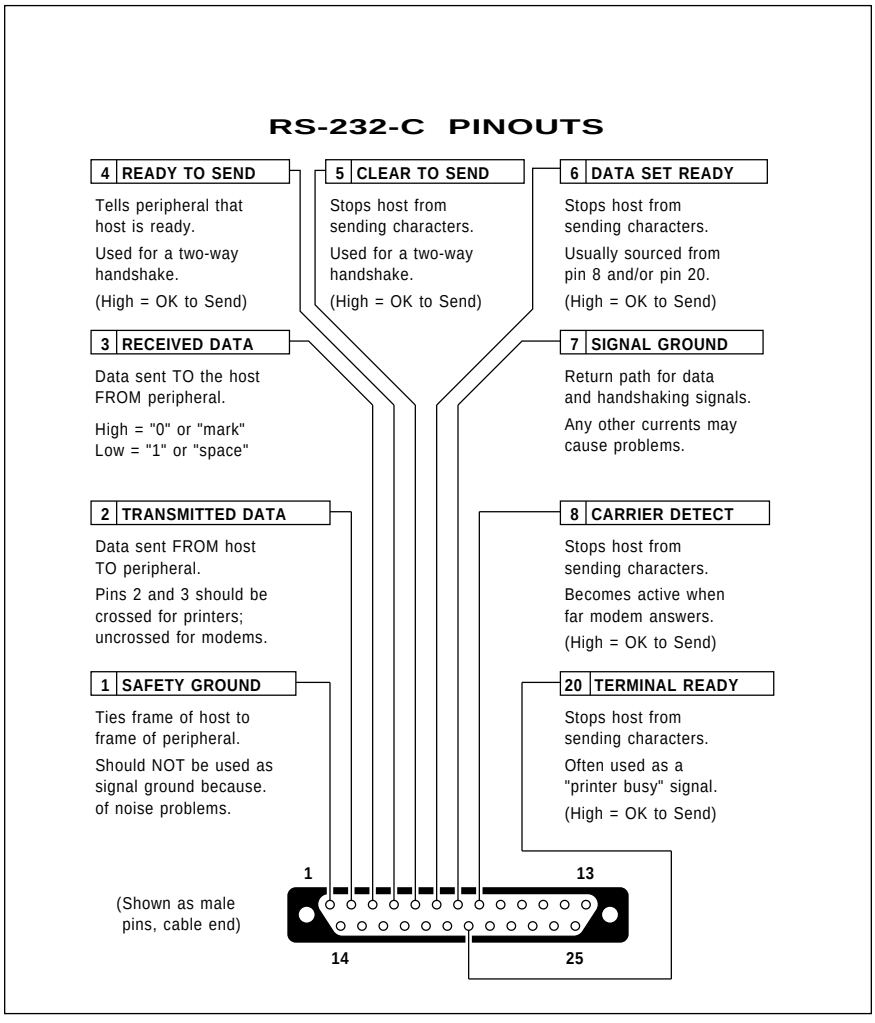


Fig. 1 – Here are some details on the RS-232 serial communications standard. Note that the data and handshake lines are often crossed for printers and uncrossed for modems.

Getting Component Parts

Getting small quantities of sanely priced electronic and other hacker components could be both a major challenge and a real hassle. On the other hand, that last helpline caller was someone who just had "looked everywhere for weeks" and could not find a plain old 500K volume control in downtown Boston.

Rule number one of all component gathering is to tune yourself in ahead of time to the sources and places where these parts can be found. And rule number two is that the bigger a hurry you are in, the less likely you will be to get the parts in the needed time frame. Or at a sane price.

Naturally, we would hope that you would begin by using all our many fine *Radio-Electronics* advertisers. All of these people have gone out of their way to provide for you small quantity components at acceptable prices. And nobody has ever gotten filthy rich by selling sinqle quantities of 555 timers to electronic hackers.

We have given you a free bingo card 1 So be sure to use it.

Arrangements are sometimes made through the author of an article to provide all the key components. This is often far and away your very best resource on any particular project, since substitutions can lead to all sorts of subtle to major problems.

Yet another obvious hacker parts source is a *Radio Shack* store. Their component selection is admittedly limited, particularly in the smaller stores. But they sure are handy.

Electronic distributors are your usual source for most components in smaller quantities. You'll find a few different types of these distributors, each one of which has strengths in certain areas. It pays to get familiar with all of them.

New age distributors are outfits like *Mouser*, *Jameco*, and *Digi-Key*. These people offer smaller quantities, reasonable prices, and often with low minimums. On the debit side, they only stock stuff that is reasonably

likely to move. They are unlikely to want to sell you anything they do not normally have in stock.

Old line distributors stock nearly everything by practically everybody and can get most anything else on a backorder basis, however obscure.

But they do have steep minimum orders, longer delivery times, and higher prices. Not to mention the distinct anti-hacker bias. Important examples of old line distributors are *Newark*, *Schweber*, *Allied*, *Hamilton*, and *Cramer*.

We saw last month how there is a separate distribution channel for the repair and replacement semiconductors and parts, with *ECG* and *NTE* being two of the leading sources.

Surplus and distress houses are other major parts sources. These will feature extremely low prices on a catch-as-catch-can basis. But, the quality can range from first rate clear on down to floor sweepings. Besides the usual ads, you'll find these outfits in the yellow pages of most any city that has a "radio row" area. Local amateur radio operators are also a good source for surplus locations.

Two of my very favorite surplus houses are *Jerryco* and *Fair Radio Sales*. The surplus price leader has to be *BNF*, but here you buys your ticket and you takes your chance.

If you need any larger quantities of quality mainstream parts in a hurry, all those distress merchandizers that advertise in the classified section of *Electronic News* should not be overlooked. A typical price and quantity might be 2000 light emitting diodes at three cents each.

Far and away the most important sources for info on any of the new components are those electronic trade journals. These include *Electronic Design*, *EDN*, *E.E. Times*, *Electronic Products*, and *Electronics*, among others. Many of these are free if you request a subscription on a suitable letterhead.

The coupons and bingo cards in all of these trade journals will then lead you to the actual data books, price lists, and application notes from all of their advertisers.

A nearly complete listing of all of the trade journals can be found in *Uhlrichts Periodicals Dictionary* at your local library.

Many of the trade journals also publish annual directories. Three of the most useful and most important are the *Electronic Design Gold Book*, the *EBG Electronics Buyers Guide*, and the *EEM Master*.

Computer Shopper magazine is far and away your best source for very extensive listings of most computer related components.

Some of the electronics houses are liberal with one or two free samples, while others are not. You will get the best results with a professional and specific request, written up on your business letterhead, and clearly explaining the intended use.

If a part seems ridiculously hard to find, this may be telling you something. One helpline caller has been on at least a dozen times, trying to find some cheaper substitute for the standard, legal, and type approved $5 modem transformer. Another is still trying to find some tunnel diodes for a construction project he found in a 1960 Australian magazine article.

Finally, there is always good old networking. Ask somebody for help. Such as our helpline, your local ham radio operator, an engineer or tech at an electronics firm, a magazine editor or author, a computer club or a radio club, or an on-line BBS system.

Understanding RS-232

It should have been flushed years ago, having all of those ridiculous connectors, its very limited range, its unworkable supply voltages, its user confusion, and its refusal to network. But, like it or not, that old RS-232 serial data communications standard is still with us, and is only starting to be replaced in only the very newest of communications systems.

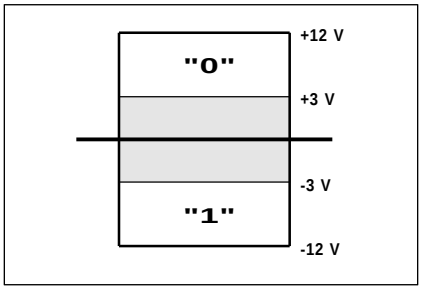


Fig. 2 – Here are the two logic levels that are normally needed for RS-232 communications. A "negative logic" convention is always used.

Figure one shows you the RS-232 standard. The big DB25 connector is normally used, having female on the machines and male on the cables. The logic levels are as shown you in figure two, with a digital "0" being a positive voltage from +3 to +12 volts, and the digital "1" having a negative voltage from -3 to -12.

While there are several ways to use RS-232 serial communications, the most popular is to apply the old *asynchronous* teletype code of figure three. By asynchronous, we simply mean that any amount of time at all can elapse between any successive word transmissions.

A character or a word gets transmitted by using a *start bit*, some number of *data bits*, starting with the least significant, an optional *parity bit*, and some number of *stop bits*. A fairly popular text character format is to use seven data bits, no parity, and two ending stop bits.

The rate at which the bits go over the interface is set by the bit rate, which is also popularly called the *baud rate*. Current baud rates include 110, 300, 1200, and 9600. It is of the utmost importance that both ends of

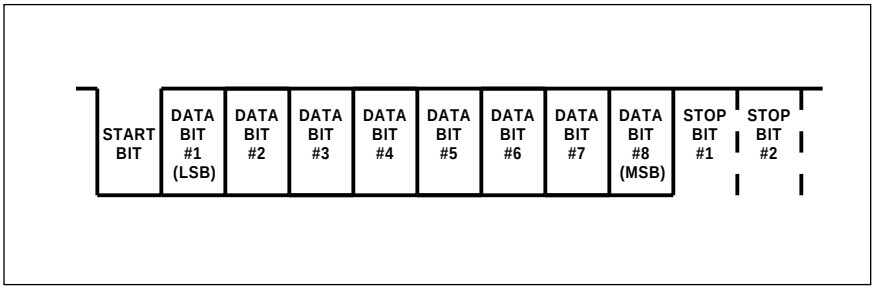


Fig. 3 – Most RS-232 serial communications will use this older "teletype" asynchronous code. Seven or eight data bits are normally used, with the least significant bit always sent first. Any number of stop bits above the minimum can be sent between successive characters.

the system always are using the *exact* same baud rate, number of data bits, the type of parity, and number of stop bits. Otherwise, your data will get trashed and be useless.

To further confuse you, there are two methods of RS-232 transmission. When using DCE or "modem" communications, there will be no data or other pin crossings, and a "straight" cable that routes pin 2 to 2, 3 to 3, etc. is most often used.

With the DTE or "printer" communications, a "crossed" cable gets used that crosses pins 2 and 3, 3 and 2, 4 and 5, 5 and 4, 6 and 20 and 20 and 6. This crossing is sometimes called a *modem eliminator*.

There are several different types of handshaking used with RS-232. When using a *hardwire* handshake, a printer busy signal originating at pin 20, or a modem carrier detect signal that will originate at pin 8 gets connected to the input busy line over on pin 6.

When you are using the alternate XON/XOFF handshaking, some extra characters are inserted into your data stream to stop and start your actual transmission process.

As with the baud rate and the data format, both ends must *exactly* agree on the handshaking.

A handshaking problem usually will not show itself immediately. It is more likely to trash things up after a page or so has been transmitted.

Details on exactly how you change these values differ with each system. Sometimes there are DIP switches at both ends that need set, while other times, you can software configure the values. Your software configuration can either be done in the program itself, or inside supervisory print or drivers or controllers.

One way to service many RS-232 problems is to start out at a very low baud rate, even as low as 110 baud. This will separate all of the handshaking problems from any of the more fundamental comm hassles. Your servicing can be done with an oscilloscope or a *breakout box*.

A good baseline for initial printer work is to separately cross pins 2 and 3 and to tie pins 6, 8, and 20 together.

One RS-232 problem unique to the COM1 port of an IBM clone is that it will expect some auxiliary handshake signals on pins 4 and 5, while most cables and most other communications do not provide these pins at all. One solution is to directly short pins 4 and 5 on the COM1 connector.

Many modern computer circuits will use a single +5 volt supply, and do not have the higher positive and negative voltages as are required for RS-232. The simple circuit of figure four handles this problem. The IC shown will internally generate all of its own +10 and -10 volts, starting with a single -5 volt supply.

The MAX232 chip is a *Maxim* product. They also stock a wide variety of other interface drivers, singles and doubles, RS232 and otherwise. All are sanely priced to boot.

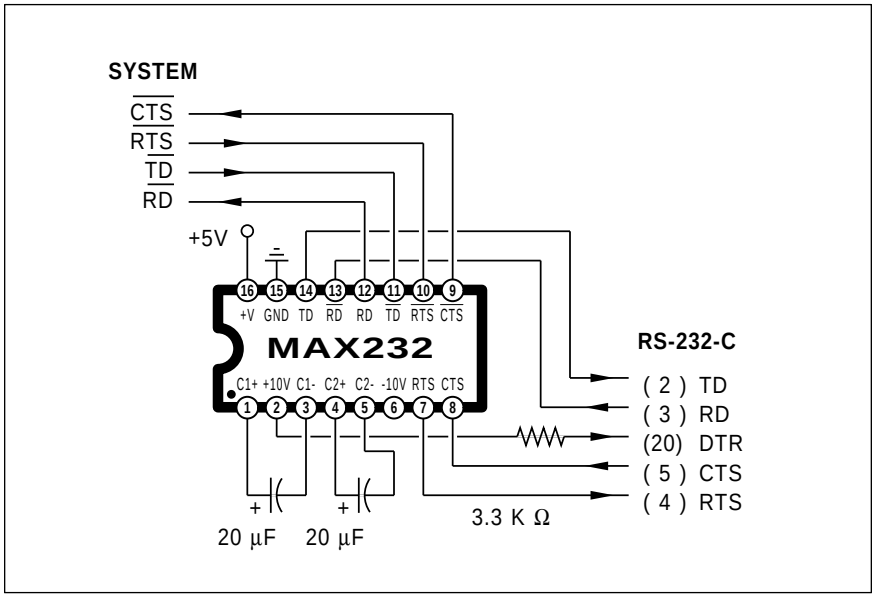


Fig. 4 – This RS-232 driver circuit needs only a single +5 volt supply. An internal charge pump circuit generates the needed +10 and -10 volts for the actual interface levels.

Memory Upgrades

We sure get a lot of questions on this topic. The caller usually has an older *Flugelhoffer-8* or whatever personal computer and had just noticed that the pinouts on today's jelly bean 256K memory chip are more or less the same as on all those 16K dynamic RAMs already in his computer.

Couldn't he simply swap out his old chips and dramatically increase all the memory he has available on his older machine?

The answer is that, yes, this is usually theoretically possible. But the time, hassle, and involvement needed to actually pull it off almost always is not worth the effort.

If 1 and this is a very big if 1 your computer already has a provision for memory expansion, then your chips can be added without much hassle. For instance, even on the earliest of 128K Macs, you were able to piggyback 512K of extra memory without creating too many new problems.

In general, though, the larger chips will do you no good whatsoever. It is only when you can simply and positively answer each of the following questions that a memory upgrade becomes reasonable . . .

(1) Where are all the extra address lines going to come from?

(2) How is the dynamic refresh and the address pin multiplexing going to be done for these extra address pins?

(3) How is memory management beyond 64K handled? By what bank switching circuitry, activated how?

(4) What modifications will be needed for the firmware monitor and the disk operating system so it can recognize the new memory?

(5) How is the existing software going to be modified to access the new memory, particularly if all your locked and protected software was sold by a now bankrupt firm?

Now, these are certainly all problems that can be solved. But the kicker is that if you are the type of person that can solve these, your time

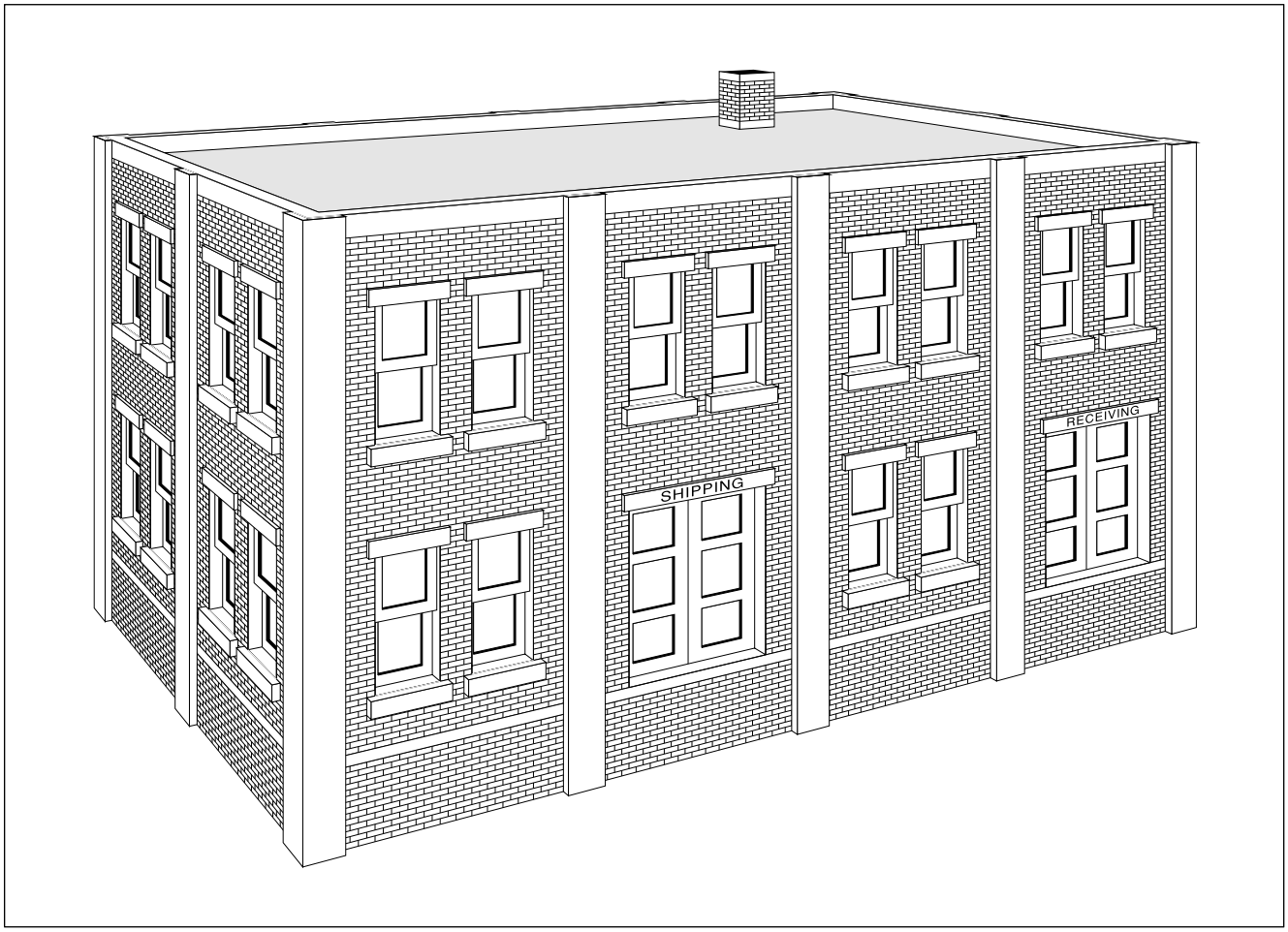


Fig. 5 – Spectacular 2-point perspective drawings can easily be done using nothing but your favorite word processor and a PostScript-speaking printer. Only a 4K text file is required for a figure this complex!

will be so valuable that you'll usually have far better things to be doing. So, while memory upgrades can be done, the chances are that it is not remotely cost effective to do so.

Perspective Transformations

I've been having a lot of fun lately with some new perspective drawing routines that I recently created. These let any plain old word processor and a PostScript printer produce some absolutely stunning graphic images. Unlike all those far more expensive routes to perspective drawing, my new routines will now automatically handle true perspective *lettering* (!) of any style in any font, along with precise perspective circles and arcs.

Yes, you can even do an animated flyby, changing both your position and viewpoint with only a very few keystrokes. All individual objects can also all be *separately* rotated inside of the total perspective drawing.

Figure five shows you a typical sample. Not too shabby for *Apple-Writer* on a IIe or IIgs, eh what? The PostScript data file on this is about the same length as a business memo. You do, of course, need a PostScript speaking printer as an output device.

What I would like to do here is share with you all of the fundamental perspective transformations. Chances are you can apply these to most any old graphics program, even by using BASIC. And it sure is fascinating to fly over a building with nothing but a couple of key strokes. Only simple high school math is involved.

The perspective most people use most often is often called *two point* perspective in which all vertical lines stay that way. The simpler *one point* perspective that you would get while looking down a long hallway both is a special and a centered case of two point perspective.

At any rate, figures six and seven show you both of the transformations needed to convert any three dimensional object or image directly into the two dimensional representation needed for a printed sheet of paper or your computer's display screen.

Let's assume you had a giant plane of glass that is between you and your subject. We'll call this pane of glass our *picture plane*. We will start our origin at the center bottom of your picture plane. We will use **xx** for the back and forth distance having right positive. We will then make **yy** the distance into the picture with the farther from you ending up as the more positive. And, we'll use **zz** for up and down with positive up.

Next, we will assume you will be

standing pretty far in front of the picture plane. We can call **xo**, **yo**, and **zo** the distance from the plane to your eyeball. In general, for the two point perspective to work, you will want to stand fairly far back, using a rather large **yo**. Otherwise, your perspective illusion will distort and fail. Many times, you might want your **zo** to end up matching your standard eyeball height, particularly on any architectural drawings.

We'll call capital **X** the back and forth distance on both the final paper and your picture plane, and capital **Y** the up and down distance on the paper and the plane. As figure six show us, two simple similar traingles are all that is needed to transform all your perspective image to your page or video screen.

All that my routines or your new computer program now has to do is solve these similar triangles for each and every endpoint of each and every line to be drawn. While painful for a people, this is utterly trivial for most any computer.

Do give me a call if you need any more input on these exciting new methods for perspective drawing.

Short Electronic Delays

I got a call from some students that were working up a dynamic memory demo as a class project and wanted to avoid buying a very expensive short time delay generator.

For most quick, cheap, and dirty time delays in the 1 nanosecond to several microsecond region, just use ordinary small coax cable or twisted pair wires. You should get around 1.6 nanoseconds per foot, or about 600 feet or so per microsecond.

The bandwidth is quite high and could accomodate either analog or digital signals with equal ease. Both ends of the cable should be properly terminated to eliminate reflections.

New Tech Info

Let's see. There's a whole pile of new data books this month. On top of the stack are the new *FET Data Book* by *Siliconix*, a *Programmable Logic Handbook* from the *Advanced Micro Devices* folks, a *Xicor Data Book* that does include info on the EEPOTs we looked at a few columns back, and a new *Optical Semiconductor* catalog from *Mitsubishi* that has got some unusual solid state laser stuff in it.

One of my very favorite low cost sources for small mechanical parts in small quantities, for robotics or whatever, are those *Small Parts* people. Besides stocking all sorts of hard to get hardware, they can also custom shear any smaller pieces of metal and plastic for you.

If you need any rubber sheeting or tubing, again at very low prices, do investigate *Hygenic*. This outfit is an especially good source for the low pressure pneumatic stuff we recently looked at.

A mounted strain gauge useful for electronic scales and whatever is available from *Revere* as their model FT-30 force translator transducer. It is available in ranges from 1 up to 40 pounds, and in resistances from 0.5 to 25 ohms. Very interesting.

The *Hewlett Packard Journal* is a good free source of technical details on sophisticated electronic devices. Their February, 1987 issue includes a good tutorial on wide range optical and infrared sensors in it.

Speaking of IR sensing, *Amperex* has some miniature and sensitive pyrolitic infrared detectors whose prices start at $3.50. This looks like a really great component, but I have not yet had the chance to test them out yet. One obvious application is in "hot spot" detectors for use by the fire service. The current devices are ridiculously expensive and many of the volunteer fire departments simply cannot afford them.

For some new information on electronic noise, and noise diodes for testing in particular, check out the *Micronetics* noise diode catalog. A good tutorial on noise and noise testing included.

Turning to my own products, if you are thinking of starting your own craft or tech venture, be sure to look into my *Incredible Secret Money Machine* book. And, through the most astounding of coincidences, I do seem to have some pre-release disks newly available on all my new *PostScript Perspective Drawing and Lettering Utilities*, as configured for most of the major computers.

Be sure to let me know what you want to see in the way of new hacker ideas, techniques, or concepts. Let's hear from you.

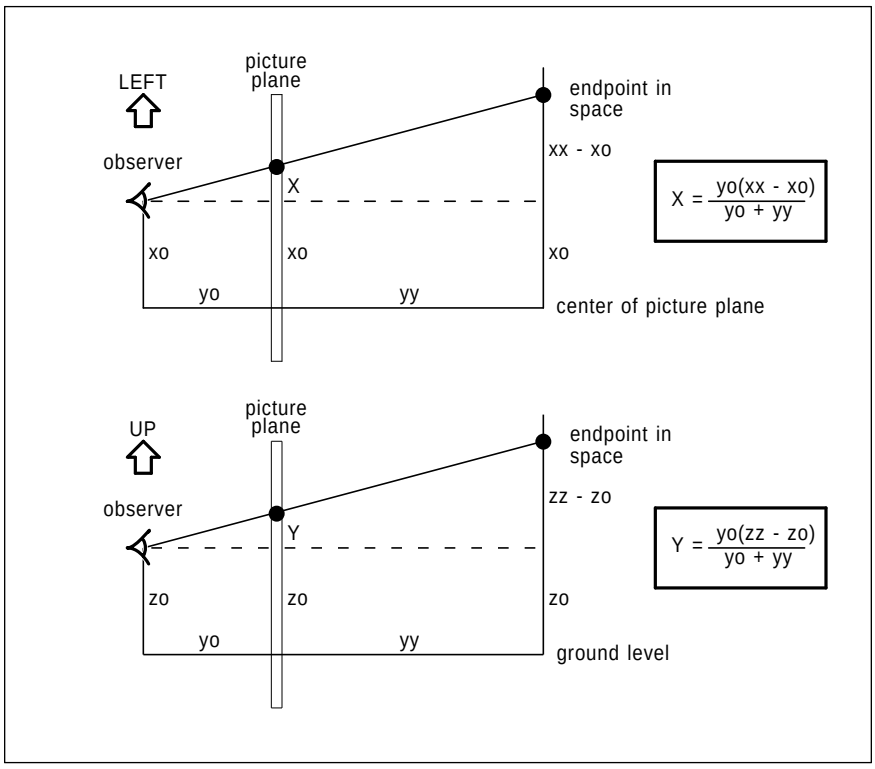


Fig. 6 – The 2-point perspective X and Y transforms. These can be easily included in a BASIC, "C", PostScript, or machine language program.

Don Lancaster's

Hardware Hacker

July, 1988

Telephone line recording
Data access arrangements
Absolute navigation ideas
Ring equivalency numbers
New printed circuit layouts

Our no-charge hardware hacker help line certainly has been busy lately. As many as fifty of you a day have called in with well thought out, interesting, and quite challenging problems. But, on the other hand, I have been getting far too many calls from those of you who simply did not read the story or else paid no attention whatsoever to all our carefully researched *Names and Numbers* sidebar resources.

Please, to make it fair for everyone else: (1) Read the *entire* column *twice* and the names and numbers section *three times* before you call, (2) Pre list all of your questions, (3) Have a pencil and paper on hand, and, finally, (4) Please do call between 8 AM and 5 PM week days *Mountain Standard* time.

If you have trouble keeping track of time zones, just remember that all of the California clocks are laid back. By the way, Arizona does remain on Mountain Standard Time all the year round. We have so much daylight that none of it is worth saving.

Needless to say, if you find my answers of value, I would not mind terribly much if you did buy something from *Synergetics*, or sent me some interesting reprints, some nuts and berries or whatever. Or helped me out with my hobby of collecting federal reserve notes.

Do you remember that thirty cent three-way surplus pneumatic valve we looked at back in the April issue? A few additional stock numbers on these are the *JerryCo* #1296, *Edmund Scientific* P42533 or else the P36716, or *C & H Sales* #SV7904.

There's lots of interesting things going on this month in those trade journals and in some other technical publications. Check back to the January 21, 1988 issue of *EDN* for a great review of new stepper motor drivers and circuits.

Two major new publications for Superconductivity now do include the *Cambridge Report on Superconductivity* and also the *Journal of Low Temperature Physics*. Since these are both insanely expensive, you might want to visit a major technical library to view them.

Steve Ciarcia has now started up a brand new hacker magazine known as *Circuit Cellar Ink* that looks like a real winner. Steve had a classic story back in our September 1980 *Radio-Electronics* on the BSR home power controllers that I still refer many of you helpline callers to.

Powerconversion has just renamed itself *PCIM*. This free trade journal is a great place to go for info on "big mutha" power semiconductors as are found in welders, electric vehicles, in high voltage deflection circuits, and in any larger robotics.

A competing magazine to *PCIM* is called *Motion* and emphasises such things as steppers and servo drives. As is typical with trade jounals, you can qualify by making a professional request on your business letterhead. Your own letterheads, of course, are utterly trivial with today's *PostScript* laser printers.

Our biggie this month is a brand new way of creating hacker printed circuits that can minimize or outright eliminate any need for camera work, yet will quickly and cheaply produce first quality results. But first, let's dream just a little . . .

Absolute Navigation

It sure is fun to try and predict when and where the next big hacker breakthrough opportunity will come from. The one I am waiting for is a dramatic price reduction in a simple, accurate, and extremely low cost system used for absolute navigation.

Figure one shows you one great possibility 1 a $9.95 and three inch *NaviCube* that always knows exactly where it is, how far it has moved in just what direction since last reset, where true north is and exactly which way is up.

I am one of those spelunkers that

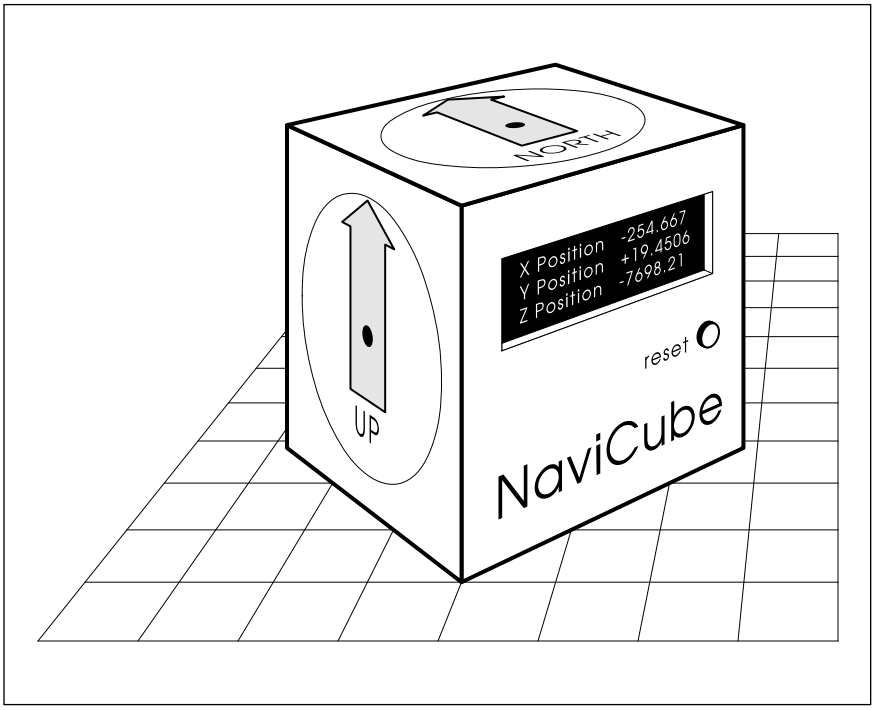


Fig. 1 – The $9.95 Navicube always knows up, north, and its own absolute position since it was last reset. Its only tiny problem is that it doesn't quite exist – yet. Or does it?

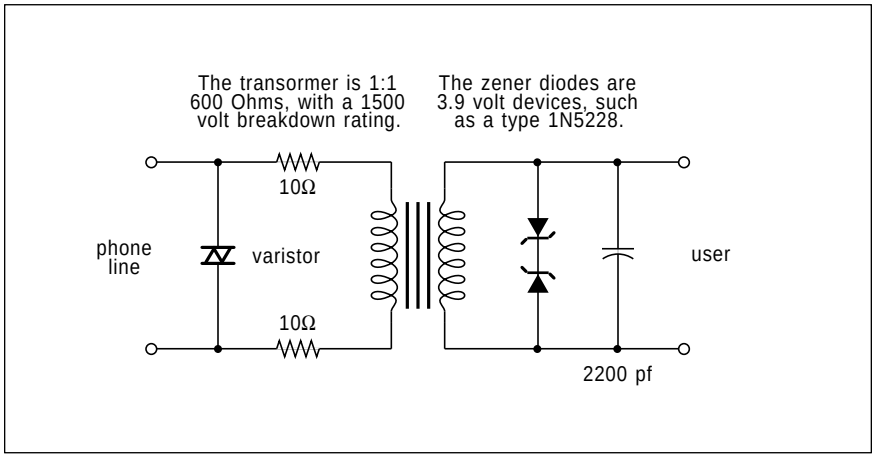


Fig. 2 – A data access arrangement such as this one must provide for surge suppression, signal limiting and safety isolation, as well as being FCC part 68 type approved.

often will spend considerably more time underground than above. Cave mapping is an weary, exasperating, tedious, and time-consuming task that is prone to all sorts of errors. It sure would be nice to throw one of the NaviCubes into my speleo pack, waltz on through the cave, and return with an accurate map.

It would be even nicer if you put the NaviCube inside a rubber ball. At each cave station, you simply would bounce it off the ceiling, floor, and walls to instantly map the passage size as well as its current position.

The traditional approach to the NaviCube is to use one or more gyroscopes. Basically, you take a freely supported large mass and spin it as fast as you can, while recording any deviations from its initial path. It usually takes three of these, one each for the X, Y, and Z directions.

You can still get the surplus World War II gyros from such outfits as *C&H Sales*, *Fair Radio Sales*, and *JerryCo*. But these are bulky power hogs that are hard to use.

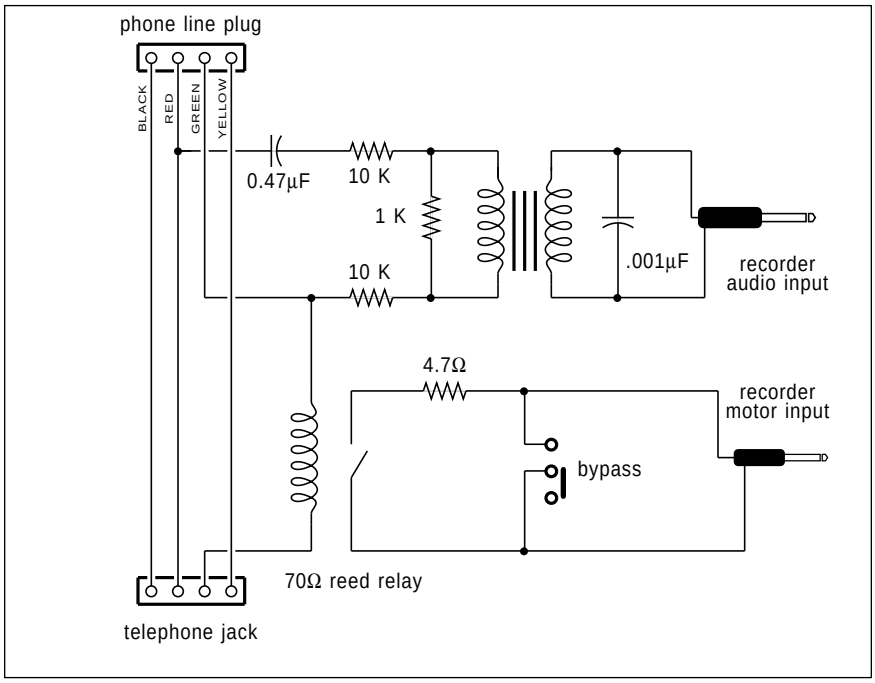


Fig. 3 – An audio access arrangement can record both sides of a telephone conversation, but is only legal for use under certain circumstances.

Today, we do have optical solid state gyroscopes that are nothing but a roll of fiber optics, a pair of diodes, and a directional coupler. Coherent laser light gets squirted in both directions around the fiber coil, and then the phase difference caused by the *Doppler effect* is measured to tell you how much the coil has rotated.

Unfortunately, solid state gyros are being built today by all of the wrong people for the wrong reasons, so they remain outrageously priced. But I feel it will only be a matter of a very few months before some Hong Kong toy company builds a $9.95 solid state laser gyroscope or its equivalent. Us hackers should be more than eager to glomp onto this jewel.

A third possibility would be to use some sort of satellite-based radio direction finding inside the NaviCube. While this is certainly possible, I feel that the resolution of this approach is unlikely to ever get much better than a few feet, and that there would be some quite serious antenna and reception problems that can limit both the minimum size and the coverage.

Not to mention that it would not work very well underground.

There is a fourth approach to the NaviCube, and it is something that all you hackers can experiment with right here and right now. The price of new high quality accelerometers has just dramatically dropped to the $10 range, led by such outfits as *SenSym* and the *IC Sensors* people.

What you do is take the output from a silicon solid state accelerometer and then A/D convert it into a series of pulses. You sum the pulses into an up-down counter to get the current velocity. Then, at precise time intervals you sum the velocity to get the current NaviCube position.

Talking some math, your rate of change of position is velocity and the rate of change of velocity is acceleration. Conversely, the first integral summation of acceleration will be velocity, and your second integral summation of acceleration will be the position. The details appear in most any college level physics book.

Newton's law and all that.

For this month's contest, let us assume that your $9.95 three-axis NaviCube is a reality and that both its stability and long term accuracy

are "good enough". Tell me what you would do with it. There will be all the usual books and *tinaja quests* as prizes. Also as usual, do send your entries to me per the box and *not* to the *Radio-Electronics* offices.

Oh yes. If you are that sort of person who thoroughly enjoys having ice water drip down their back while trying to munch a soggy and spent carbide flavored sandwich by the light of a fading greenish *cyalume,* then give the *National Speleological Society* a call. They will in turn put you in touch with a local *grotto* or two in your immediate area.

Are we having fun yet?

Data Access Arrangements

A data access arrangement is any scheme to get modem tones or other audio or control signals onto or off of the phone line. The laws on how you do this will change from country to country, but in the US you are supposed to exactly follow part 68 of the *FCC Regulations*.

Simply meeting the regulations is not nearly enough. Besides this, your circuit or product has to be *type approved* before it can be sold. And getting FCC type approval is usually a costly and very drawn out bureaucratic nightmare.

Figure two does show you all the essentials of a typical data access arrangement. You start off with an 500 volt or so varistor or else a telephone grade transient suppressor on the phone line side. A pair of ten ohm resistors is then used to drive an audio coupling transformer. This transformer usually has 600 ohm input and output impedances, and *must* have a breakdown voltage of at least 1500 volts.

The de-glitching capacitor will be required on your transformer secondary, as will be a pair of series connected zener diodes that will prevent you from ever applying more than plus or minus four volts of peak-to-peak signal onto your telephone line.

Ready-to-use and previously type-approved data access arrangements are available from such outfits as *Cermetek* and *Dallas Semiconductor*. The prices are ridiculous.

The leading US manufacturer of the special transformer required is *Prem Magnetics*. As one alternate, *Newark Electronics* lists a *Stancor* TTPC-7 equivalent that sells for $5.63 in modest quantities. Surplus bargains on these also may show up.

A second variation on an audio access arrangement is shown you in figure three. This circuit might let you automatically record any phone messages. You will find two main areas to the circuit.

The first area consists of a very sensitive reed relay that pulls in only when the phone is on hook. When you pick up the telephone handset, the DC loop current goes through the reed relay and thus activates it. Since the reed switch is *normally open*, the switch will turn *on* your recorder when the handset is picked up.

The second area of the circuit is a suitable audio transformer that will couple the phone line audio into the recorder. Note that this is a one way circuit 1 you can record your phone messages, but you can not play the recorder back into the telephone line.

Because of the drop across your relay coil, this circuit only will work with a single telephone. A fancier circuits is needed when extension phones are present.

The *Radio Shack* model 43-228-A uses a circuit similar to this one.

Ringer Equivalency Numbers

There sure seems to be a lot of confusion on what is really a very simple concept. Most of the urban telephone systems let you put *five* of the older telephones on them, using five electromechanical bell ringers. A smaller rural phone outfit may limit you to three bell ringers.

Each piece of new phone gear that gets placed on your phone line must have a label on it that tells you just what the *Ringer Equivalency Number,* or *REN* is. A plain electromechanical bell has a REN of 1.0.

When you add up all of the REN values for everything that you have hung on your line, the total must be less than five for an urban phone and less than three for the longer rural phone lines.

In theory, your phone company can adjust your line for higher ringer loads, but my local phone company refuses to do so. Mountain Bell.

Phone ringing is done by placing a high voltage and low frequency sinewave onto the line, typically in the range of 40 to 150 volts with a frequency of 15 to 68 Hertz.

In previous columns, we have seen several special integrated circuits you could use for ring detection or for speaker or piezo transducer driving. Figure four shows you a simpler and much more flexible approach that uses an ordinary optocoupler instead.

The zener diodes ignore voice and smaller amplitude glitches. Only the tops of the strong ringing sinewave get used to activate the optocoupler. This prevents false ring signals from inadvertently tripping whatever you happen to have connected to your detector. Such noise immunity gets extremely important for most users, especially for unattended operation.

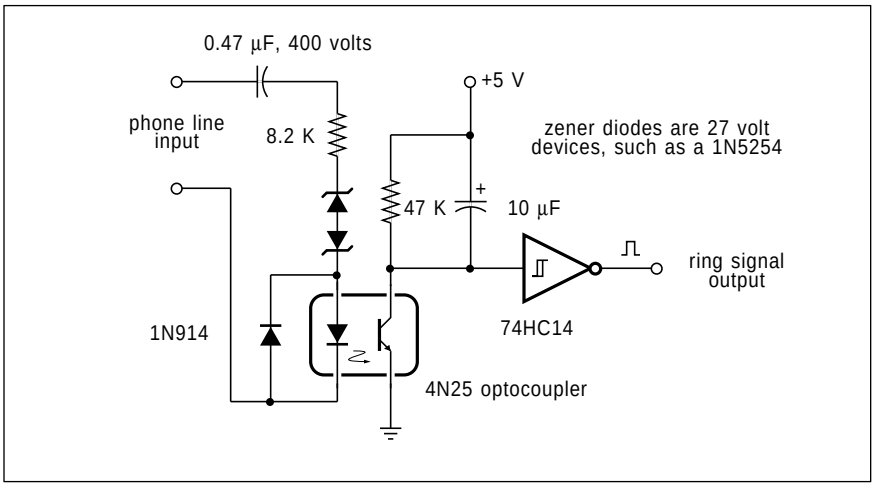


Fig. 4 – A telephone ring detector. The optocoupler provides safety isolation, while the capacitor converts the individual rings into a continuous signal.

New Printed Circuit Layouts

I have been putting together a new way of doing hacker and student printed circuit layouts that seems to have a bunch of advantages. It will instantly, and without using any photography, produce for you 1X, 2X, or even 4X layouts, frontwards or backwards, positive or negative, of any size from one square inch to one acre. And it is cheap.

The system does use your favorite word processor on *any* computer and can directly drive a *LaserWriter* or other *PostScript* language printer.

A typical layout is shown in figure five, where we have overlaid the design grid, the foil side in black and the component side in gray. Up to a dozen layers can be shown at once.

Since everything is done in "raw" PostScript text, you can very easily rearrange the scenery to suit yourself in any way you like. I usually start with a fine gray grid, and then overlay the foil and component sides as needed, using some of my opaque grid-based "icons" that handle all the traces and pads.

The process now provides a 3 mil resolution and supports details of 10 mils or wider. For many hacker uses, you might directly print 1:1 onto mylar overhead transparency material, thus generating your negative or positive as needed.

For more serious applications, you can work two times or four times the final size and gain the corresponding increase in resolution or precision. Should the final image be larger than one page, it can be automatically printed on as many pages as are required. These pages can then be taped together.

You can instead run all your final results on a PostScript phototype-setting machine if extreme accuracy is needed.

Note that the method *demands* a PostScript speaking output device.

One highly intriguing additional possibility is to do a 1:1 layout onto a suitable transfer material and then ironing the transferred toner directly onto your bare PC board, followed by an immediate etch. Unfortunately, this particular sub-process isn't quite reliable enough just yet. But do stay tuned for more details.

New Tech Info

Newark Electronics has released their fat 1042 page catalog number 109. Of all those traditional "old line" electronics distributors, they have always been one of my favorites. While they stock just about everything in a dozen locations, they tend to be both pricey and more than a tad anti-hacker.

Or, for a much smaller "new age" distributor that goes out of their way to stock single quantities of highly interesting hacker integrated circuits, try *Circuit Specialists*. Among their numerous other goodies, they now stock the *Sprague* ULN2429 liquid level detector we did look at a few columns back. Cost is only $1.80.

The *Micro Switch* people have a free *Specifier's Guide for Pressure Sensors* in print. But the *SenSym* people have far better ap-notes and much better pricing when it comes to hacker pressure transducer and interface stuff.

The *Mitsubishi Series 740 CMOS Microcontrollers* are outlined in a new and free brochure. These 6502 style devices form the best selling microcomputer chips in the world today. My personal favorite here is the M50734, a 128K beastie that includes 40 parallel I/O lines, a built-in serial UART, four A/D converters, two stepper motor drivers, a watchdog, five timers, a pulse position modulator, and a soft ice cream dispenser.

There's even enough pins on it that you can use it in a pinch as an emergency cheese grater.

We will see much more on this hacker gem in future columns. By one of those absolutely astounding coincidences, that M50734 just happens to drop right into the printed circuit shown in figure five. Any old Apple IIe, IIc, or IIgs works just fine as a development system.

Turning to my own stuff, check into my classic *TTL* and *CMOS Cookbooks* if you happen to be interested in all of the fundamentals of digital integrated circuits. Something around 1,400,000 copies are now in print, which is some sort of a record for technical paperbacks.

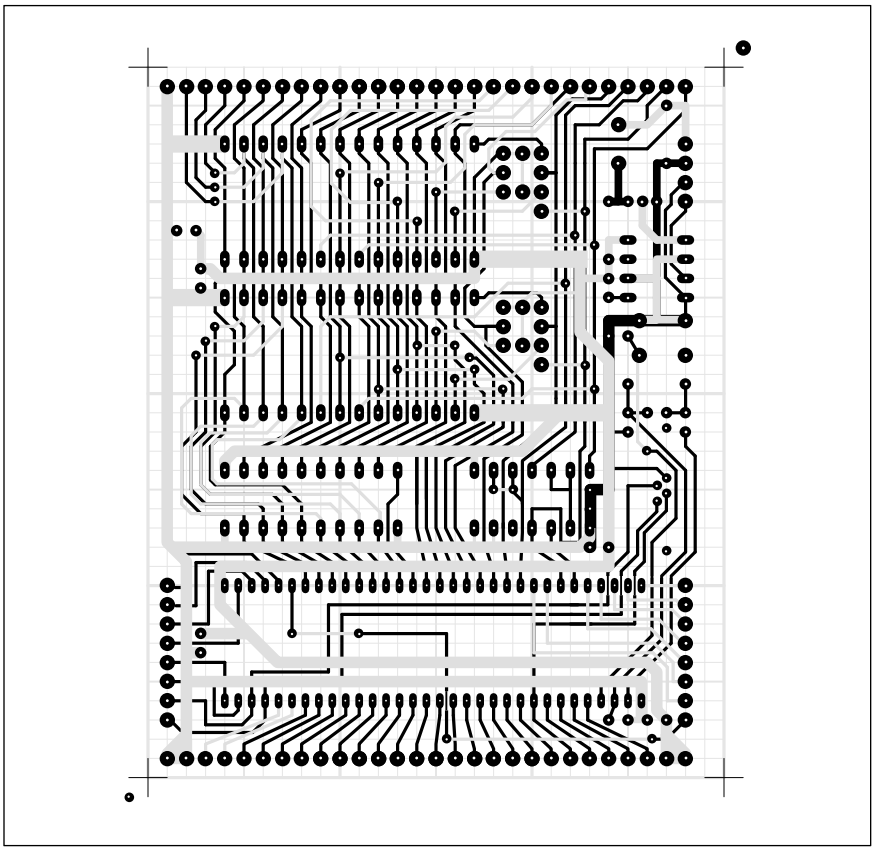


Fig. 4 – A typical PostScript 1:1 printed circuit layout.

Don Lancaster's

Hardware Hacker

August, 1988

Remote controls
Infrared receivers
A new A/D converter
New data book resources
Analog computer interfacing

We'll start out with our usual reminder that this is your column and that you can get both tech help and off-the-wall networking by calling the Guru hisself per the *Need Help?* box at the end of this volume. The best calling times are weekdays, 8-5, *Mountain Standard Time.*

Also as is usual, I have gathered pretty near every source mentioned here into a common *Names and Numbers* table, found at the end of this volume.. These addresses are where you go to get more info or to follow up on any specific product or data.

Let us see. I have found another low cost source for those data access arrangement telephone transformers that we looked at last month. Check out the TTC-142 from *Tamura*. These are under a dollar in large quantities.

The developments in superconductivity continue at an amazing pace. By switching to materials made from aluminum, barium, and the thallium used in rat poison, the critical temperatures have been raised another 30 degrees to 120 Kelvin. Which is now half way up to dry ice temperature.

The new materials are also much cheaper and more stable. It remains to be seen whether the final current densities will end up high enough for real-world uses.

One good source for all superconductor info is the *Science* magazine, which is published by the *American Association for the Advancement of Science*, and is available at most of your larger libraries. The new 120 K superconductors are detailed in their February 26 issue.

Onward and upward . . .

Remote Controls

There seems to be plenty of help line interest lately in remote control circuits. All of you *Radio-Electronics* hackers are now trying to remote control everything from HO gauge trains through hi-fi audio, other home entertainment, to the command of an amazing assortment of robotics, aides for the handicapped, on up through industrial process controls and even full size racing cars.

It turns out there is no "best" or even a "standard" way of handling a remote control problem, nor is there a single circuit that will do all things for all people. It will depend on what you are remote controlling over what channel, how reliable the control has to be, how many others are using the same channel, the amount of security required, the available power, what types of outputs you need, etc . . .

The popular carriers for remote control include tones over the phone line; fiber optics; radio links that include ham and CB; sonic and ultrasonic sound; those AC power line RF techniques; both regular and infrared light; and all of those usual computer networks and serial data channels.

Remote controls these days are usually digital and often are microprocessor controlled. Any analog or varying signals (such as audio or the flaps on a R/C model plane) will be handled by some digital scheme, perhaps by using a pulse position or else a duty cycle modulation.

At any rate, I've just run into two outstanding free data books from a pair of wildly different integrated circuit manufacturers that should keep you busy for several years worth of remote control hacking.

Start out with the bright green new *Integrated Circuit Solutions for Communications* product data book from *MX-COM*. These folks build specialized integrated circuits for both the telephone and radio communications trade. Your typical single quantity chip prices are in the $10-25 range.

Several of their more interesting devices include their *MX204* speech scrambler, their brand new *MX403* selective calling transponder, their older *MX315* tone controlled squelch circuit, and their *MX205* digital tone generator chip.

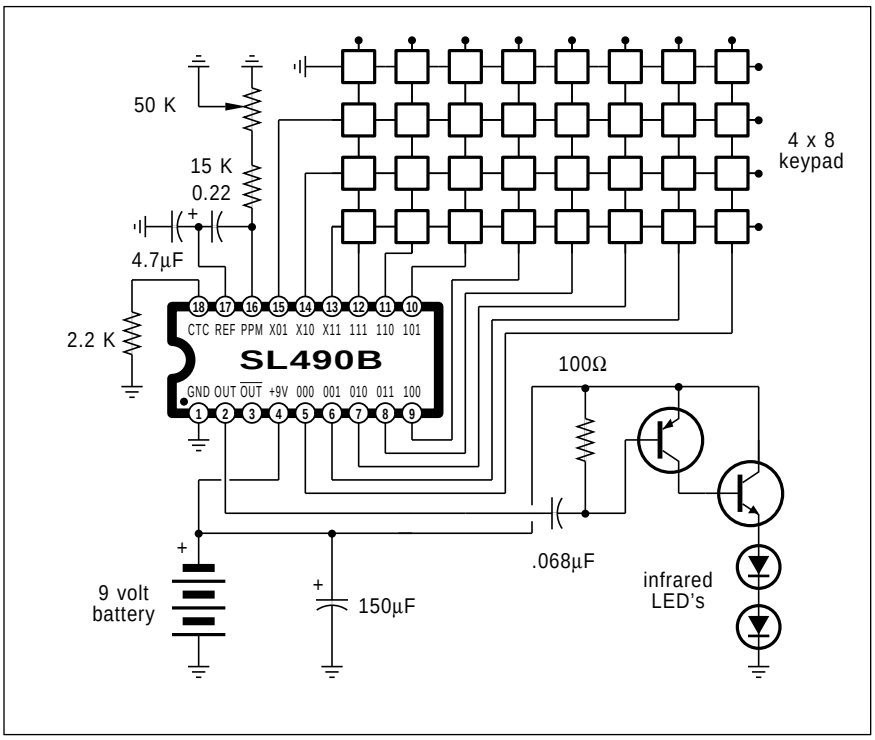


Fig. 1 – This handheld infrared remote control transmitter can send up to 32 different commands. Each command outputs a repeating code consisting of six brief pulses of infrared light.

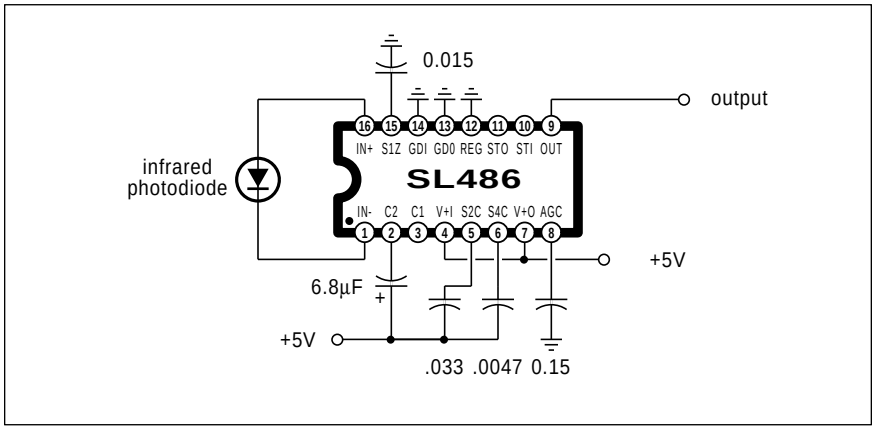


Fig. 2 – An infrared remote control preamplifier is usually needed between your receiving photodiode and the final digital decoder circuitry.

Then, check into that bright magenta *Satellite, Cable and TV Integrated Circuit Handbook* from *Plessey*.

There are many dozens of highly interesting and low cost circuits here. Once again, it will take years to fully explore all of the hacker potential of these unique chips.

As a ferinstance, we can start out with their SL490-B remote control transmitter shown in figure one. The intended use is for a hand held and battery powered infrared remote control transmitter, as is popular with tv sets and VCR's.

The same circuit can be used with ultrasonic transducers or on most any other control channel.

Up to 32 commands are available. This chip uses a five-bit pulse position modulated code. When used with infrared diodes, pulse widths of 15 microseconds are also used. The five-bit words gets sent out most significant bit first.

The timing period of a digital logic "1" varies with the application, but is usually made as long as is possible. Otherwise, functions such as a tv volume control may change too fast to be usable. A digital logic "0" will always be 1.5 times the timing period for the logic "1", while the word interval delay will be 3 times whatever the "1" period was.

Each of the command sequences is made up of six pulses. The first is a start pulse. The second pulse gets delayed by the "1" or the "0" time of the most significant command bit. The third pulse is delayed by the "1" or the "0" time of the next command bit, and so on. The six pulse groupings will continue as long as your key is held down.

Note that zero current limiting is provided for the infrared light emitting transmitting diode or diodes. It is thus super important that your circuit layout will discharge only a tiny portion of the 150 microfarad capacitor charge into the output LED per pulse, and that the supply voltage to the chip itself not drop in the process.

While pretty near any infrared LED could be used, you will get the best results with one or two high power, high brightness lamps, driven by a suitable pair of high gain, and higher pulse current transistors.

The output infrared power can be increased by use of a mirror or else a directional reflector.

Infrared Receivers and Decoders

There are many suitable decoder chips and circuits that are detailed in the *Plessey* handbook. These change with whether you will need analog outputs for volume controls or whatever and upon whether you are in a television or computer environment.

Figure two shows us an infrared preamplifier circuit which will automatically convert all of the received infrared pulses into some noise-free digital pulses of exactly the correct amplitude for further processing. A two-chip receiver normally gets used, with the preamplifier receiving and cleaning up all of the pulses, and the separate decoder converting all of the received code bursts into the actual output commands.

The data book does include one suggested pc circuit layout for their SL486 preamp. An infrared sensitive photodiode gets used for the light receiver, while the capacitors shown provide bandpass filtering for good noise rejection.

The preamp circuit will normally be placed inside a shielded case that has a plastic filter in front of it that will freely pass the infrared, yet still reject room illumination.

This month, let's have us a double contest. Just dream up a new or an unusual remote control application, or else an off-the-wall use for the upcoming A/D converter circuit of figure three. There will be the usual *Incredible Secret Money Machine*

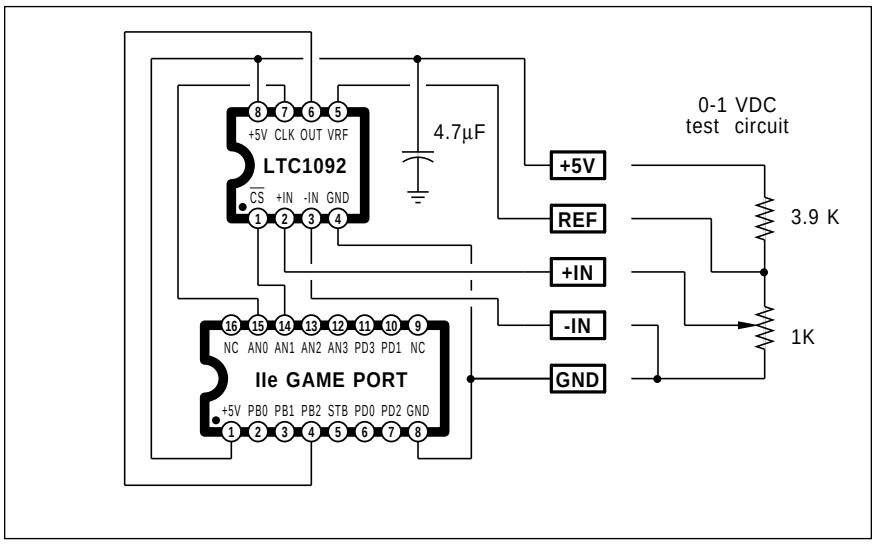


Fig. 3 – This 10-bit floating point a/d converter is very easy to interface to an Apple IIe, IIgs, or most any other personal computer or microprocessor.

book prizes to the top twenty entries, along with an all expense paid (FOB Thatcher AZ.) *tinaja quest* to the best entry of all. Please send your entries directly to me, and *not* to the *Radio-Electronics* offices. Paper designs are just fine; you do not have to build or test your entry to enter.

An Amazing A/D Converter

There is a new analog to digital (A/D) converter out that I have been really impressed with. It is called the LTC1092 and is made by the *Linear Technology* folks. Cost is around $12.

The resolution is 10 bits, which does mean that you can accurately and linearly slice an analog signal into 1024 pieces. It can run as fast as 50 kilohertz and includes its own internal sample and hold circuitry.

Since the LTC1092 is an 8 pin mini-DIP serial device, it is easy to interface to most any microcomputer or personal computer. It will run off a single +5 volt power supply.

What I like best of all about this beast is that it uses a *floating point* reference voltage. By lowering this floating reference, you can directly handle ridiculously smaller input signals. In fact, you should now be able to run a temperature transducer or even a pressure sensor into this chip without needing any fancy pre-amplification or conditioning.

Put another way, the chip can give you a 10-bit resolution over a 16-bit dynamic range, all at a tiny fraction of the cost of a real 16-bit A/D converter. Which should enormously simplify hacking just about everything from postal scales to hot tub controllers, on through stream gauges and audio processing.

Figure three will show you a test circuit I worked up that can plug directly into the game paddle port of an Apple IIe or IIgs. All of the waveforms involved are shown you in figure four, while both the machine language driver and the Applesloth controlling program appear in figure five. Finally, figure six shows you a possible pc layout.

You connect the chip to +5 volts and ground through the supply pins. There are three pins on the input side called the (+) input, the (-) input, and the reference input. The voltage *difference* between the (+) input and the (-) input is compared against the reference. A zero or a negative difference will get you a zero output, while a difference equal to or greater than the reference gets you "all ones" or decimal "1023".

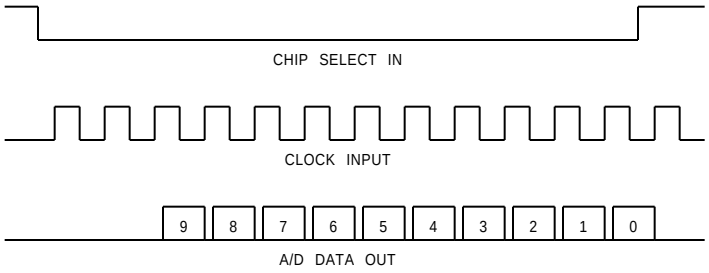


Fig. 4 – The timing waveforms used with the LTC1092. Your computer or other external timing inputs a chip select and thirteen clock pulses. Then, the LTC1092 responds in turn with ten A/D serial data bits. The A/D conversion speed can be as fast as 45 kHz.

In between, the output number is linear with the input voltage difference. For instance, a difference of one-half the reference will get you level 512 and so on. The (+) and (-) input impedances are both very high, while the reference input will appear like a 7K load impedance.

There are three pins on the output side. The first is known as the *chip select.* Your computer or an external timing circuit brings this low at the start of a conversion cycle, holds it low for a complete conversion and finally releases it back high again.

A second pin is called the *clock.* Your computer or else an external timing circuit delivers *thirteen* clock pulses during a conversion, by first bringing the clock high and then returning it back low again. The clock frequency must lie somewhere in the 10 to 500 Kilohertz range.

The A/D conversion circuit is the *successive approximation* type. Your clock-to-clock pulse spacing does not have to be a constant. Which greatly simplifies using software to generate

1. To CREATE your machine language driver, get into BASIC.SYSTEM and then do a CALL -151. Then enter the following code in this order . . .

```
300: 02 02 2C 5A C0 2C 58 C0 2C 59 C0 2C 58 C0 2C 59 <cr>
310: C0 2C 58 C0 2C 59 C0 A9 00 0E 63 C0 2A 2C 58 C0 <cr>
320: 2C 59 C0 0E 63 C0 2A 8D 01 03 2C 58 C0 2C 59 C0 <cr>
330: 0E 63 C0 2A 2C 58 C0 2C 59 C0 0E 63 C0 2A 2C 58 <cr>
340: C0 2C 59 C0 0E 63 C0 2A 2C 58 C0 2C 59 C0 0E 63 <cr>
350: C0 2A 2C 58 C0 2C 59 C0 0E 63 C0 2A 2C 58 C0 2C <cr>
360: 59 C0 0E 63 C0 2A 2C 58 C0 2C 59 C0 0E 63 C0 2A <cr>
370: 2C 58 C0 2C 59 C0 0E 63 C0 2A 8D 00 03 2C 5B C0 <cr>
380: 2C 58 C0 2C 59 C0 60                           <cr>

BSAVE DRIVER.1092.1, A$300, L$87 <cr>
```

2. To ACCESS your machine language driver, use this BASIC program . . .

```
100  PRINT CHR$(13); PRINT CHR$(04); PRINT "BLOAD DRIVER.1092.1"
200  CALL 770
300  PRINT PEEK (768) + 256 * PEEK (769)
400  GOTO 200
```

Fig. 5 – This Apple IIe/IIgs software driver will let you directly interface a high quality 10 bit A/D converter from your computer's game I/O connector.

all of your needed clocking pulses.

The analog input only has to be constant and present during the first 2-1/2 clock cycles. This is called the *acquisition time*. The input reference is internally held for the remainder of the conversion interval. This often can eliminate the need for any external sample and hold circuit.

The LTC1092 outputs data in the following manner: One microsecond after the third clock pulse, the most significant bit B9 is output. One microsecond after the fourth clock pulse, the next B8 bit is output. This continues until all ten bits are output. It is up to your computer or else your external hardware interface to catch each of these bits on the fly.

A/D Controlling Software

It is fastest to generate your clock pulses with add-on hardware, but the Apple IIe and IIgs can manipulate their game port lines fast enough that you can get over a 6 kHz conversion rate using nothing but machine language software or firmware.

This is ridiculously faster than is needed for most popular hacker uses, particularly for such applications as recording temperatures.

Use of the BASIC language will, of course, slow you down bunches. One hundred or so conversions per second is a typical upper limit for a simple BASIC program.

Over on the game paddle port, the annunciator AN1 is used as the chip select line, and AN0 is used as the clock. Data is input on the PB2 line. The machine language driver simply drops the chip select low, then outputs eleven clock pulses, and finally returns the chip select high.

Just following the third through twelfth clock pulse, the received data is routed into two registers with the eight *least significant* binary data bits ending up in location $0300, and otherwise known as decimal 768. The two *most significant* binary bits end up in location 0301, or decimal 769.

In the simple example shown, the Applesloth program will do a 10-bit binary to decimal ASCII conversion for you and show it on the screen.

Oh yes. About that jitter.

A one bit resolution with a one volt reference ends up as less than a millivolt. If any ground currents or any other type of noise gets into your inputs or reference, it will be duly converted over into a 10-bit accurate result and cause all your answers to bounce around a bit.

Extreme care must be used when shielding and guarding both of the inputs and the reference, particularly if you are going to run with very low reference inputs. Printed circuit boards and good shielding are a must. But this is what the black magic of analog circuit design is all about.

Yes, I have a source code listing available on this. Let me know if you want a copy. Similarly, if you work up a driver for some other computer, send in a copy so we can share it with the others.

Their are some other chips in the LTC12092 family that have multiple channels. You might like to look into these as well.

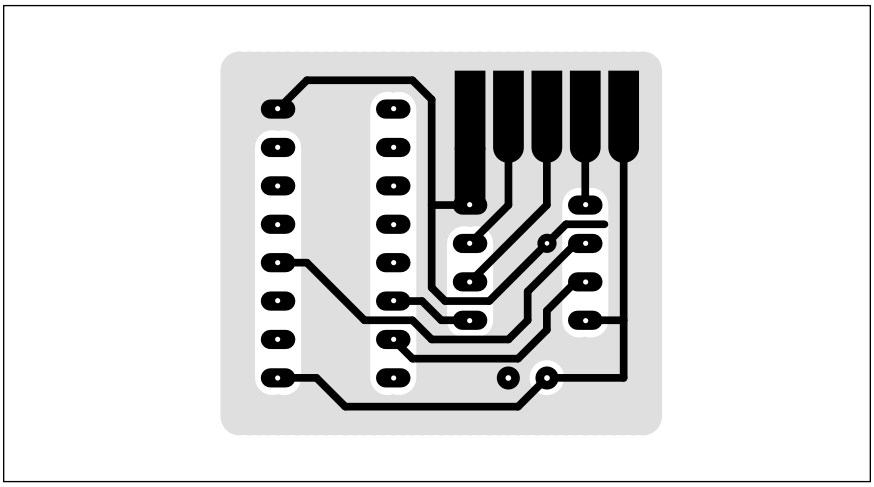


Fig. 6 – One possible pc layout for your converter. The ground plane on the component side is an absolute must! The view here is from the foil side.

New Tech Literature

Texas Instruments has a new and free *Advanced CMOS Logic Designers Handbook* out, but watch all the fine print here. TI opted for some non-standard chip pinouts and did some other rather bizarre things with their new high speed logic family. They have also gone way overboard on laughingly arcane and confoundingly obtuse new logic symbols.

There is a sequence of new *The Brighter Power* booklets available from *SGS-Thomsen*. These include chips to handle Detroit's latest buzzword 1 *high side drivers*. The high side driver lets you ground the other side of a lamp, coil, solenoid, valve, or whatever. Yes, high side driver circuits are smart enough to shut themselves down on a short circuit, a current overload, excess temperature, or an open ground.

Other data books this month do include the new *LCA Applications Handbook* from *Monolithic Memories* on hacker programmable gate arrays; a *Smart Analog* data book from *Crystal Semiconductor* about their telephone chips and their A/D converters; and a great book on *Analog Signal Processing Integrated Circuits* from *Reticon*.

There is a new trade journal out called *Personal Engineering* that you may want to try and qualify for. And *Alcoswitch* has a fat new catalog of all sorts of switches and similar hardware available.

Turning to my own products, if you are into the fundamentals of microprocessors and microcomputers, please do check out my *Micro Cookbooks*, volumes I and II. I have got two new utility packages for those of you now using PostScript speaking laser printers 1 one for the hacker printed circuit layouts and a second for creating two point perspective drawings.

And, yes, we should soon have a complete set of *Hardware Hacker* reprints available, going all of the way back and including a master names and numbers section.

For more Apple stuff, see my *Ask The Guru* column over in *Computer Shopper* magazine.

Don Lancaster's

Hardware Hacker

September, 1988

Electronic references
16-bit converter chips
Synchronous inverters
A/D conversion secrets
Apple computing books

Congratulations go to Rick Stanley from Bloomsburg, Pennsylvania for his winning of our first prize *tinaja quest* in that pneumatic valve hacker applications contest. Rick's *Air-Dale* automatic dog watering machine won paws down, while his *Air-O-Smith* guitar playing machine ended up in a class by itself.

As per usual, this is your column and you can get both tech help and off-the-wall networking by calling up the Guru hisself per the *Need Help?* box at the end of this volume. Best calling times are during weekdays, 8-5, *Mountain Standard Time*.

Also as per usual, we have again gathered all of the *Names and Numbers* together for you into one master table at the back of this volume. This is where you go for further tech info on any of the items mentioned.

A bunch of positively ridiculous breakthroughs in hacker A/D converter pricing, availability, and their performance have happened in the last few weeks. The rule seems to be this: If the ink on your A/D data sheet is not still wet, then you are dealing with an overpriced and obsolete part.

The best place to start on all this is with some . . .

A/D Conversion Fundamentals

The A/D Converter, or (ADC) is most any electronic device to change varying or *analog* inputs into *digital* pulses or numbers. Two major specs of an ADC are its *resolution* and its *conversion speed.*

The resolution will determine the best *possible* output accuracy and is normally expressed in *bits*. An 8-bit ADC can resolve up to one part in 256. A 10-bit ADC can resolve up to one part in 1024. 12-, 14-, and 16- bit ADC's can resolve 4096, 16384, and 65536 sep- erate analog levels.

But note that a 16-bit ADC will only give you a 16 bit result for a full scale input, and then only if the input signal has not been corrupted by any noise or frequency limitations.

For instance, a 16-bit ADC with a four volt reference gives you sixteen bits of resolution for four volts of input, fourteen bits of resolution for a one volt input, only twelve bits for a quarter volt input, and so on. The minimum input signal that could be converted is often set by the *quantization noise* of the A/D process itself.

Your conversion speed is simply how many conversions per second the ADC is capable of. Examples here include the *instrument* circuits that can quite accurately handle only a few to a few hundred conversions per second; *telephone* chips that work in the three to six Khz range, *Audio*, or CD converters that operate near 40 Khz, *Video* A/D circuits that will perform at 15-25 Mhz, and, finally, the expensive *Radar* A/D converters that extend beyond 200 Mhz.

There are a number of different methods of doing an A/D conversion. The fastest is called a *brute force* or *flash* converter type, in which a pile of comparators is put to use, having one for each input level. A variation on the flash converters uses the new *feedforward* conversion process.

With feedforward conversion, one half of the bits will first get flash converted, and the remainder error is calculated. The remaining half of the bits are then flash converted and then combined with the previous conversion. Feedforward converters run at one-half or less of the flash converter speeds, but will end up needing far fewer internal comparators.

Most video converters are of either flash or feedforward types. A/D radar converters of necessity must make use of flash conversion. They can end up insanely expensive.

One of the more well known older conversion methods is known as *successive approximation*. In this, one half of the reference is subtracted from the input so long as a positive result remains. Then, one-quarter the reference is subtracted, which in turn gets followed by subtractions of one-eighth, one-sixteenth, etc< These successive approximation converters can be fairly simple and fairly cheap. The uses are typically in the medium speed and medium resolution areas.

Some telephone A/D converters are also called *companders*. These will do a non-linear conversion where the small signal levels will get sliced up finer than larger ones. This way, you can digitally represent a 12-bit range with an 8-bit non-linear output.

Those instrument A/D converters normally run much slower than all of the others can, while providing much higher accuracy. Classic conversion schemes here include the *dual slope* and multiple slope conversions. Here the input will linearly charge up an integrating capacitor and a precision reference then discharges it. By then measuring the discharge time, you can end up with a number equal to the input analog voltage or current.

One very important feature of most instrument converters resides in their

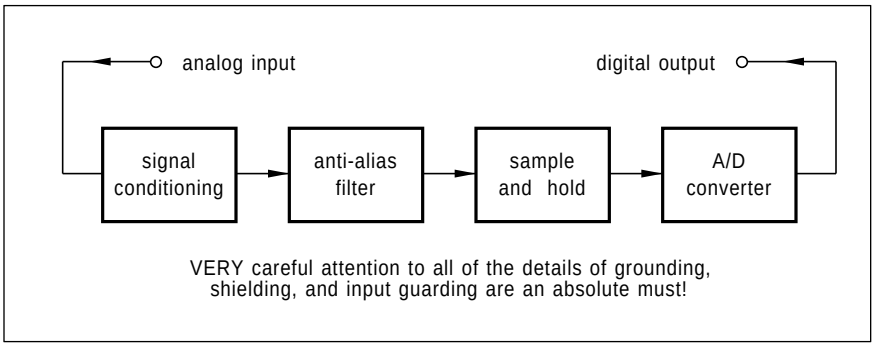


Fig. 1 – An analog to digital conversion system normally will need all of the areas shown here. Often, the A/D converter chip itself will be the least of your worries.

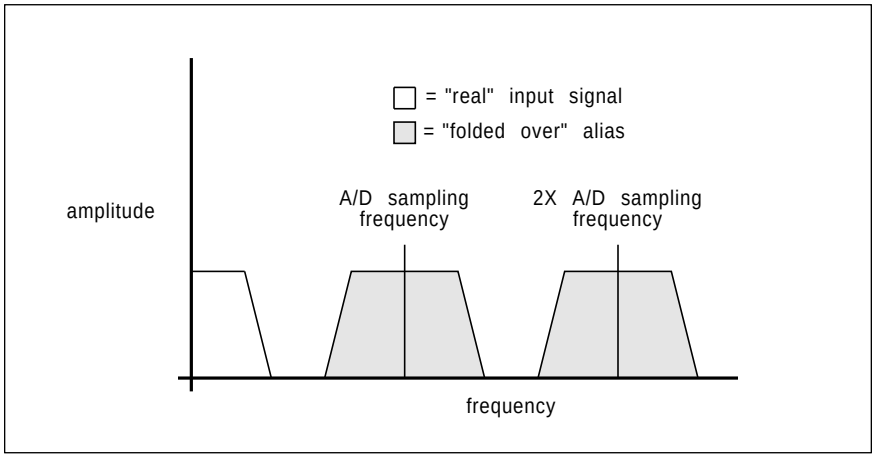


Fig. 2 – An anti-aliasing filter absolutely must be used with any A/D converter so as to sharply reject any and all frequencies above one-half of the sampling frequency. Should any higher frequencies remain present, they will "fold over" and form aliases that end up looking just like "real" input signals.

ability to reject power line frequency noise or hum. This gets done by converting exactly at the power line rate or a submultiple.

Other A/D conversion schemes do include all those *voltage to frequency* converters and *charge balancers*. In a charge balancer, the input will continually add charge to an integrating capacitor, while the output will try and remove the charge in discrete current-time packets. The number of packets removed is proportional to the input voltage or current.

But the latest, and by far the most bizarre of A/D converters are called *oversampling* converters that use an elaborate *decimation* and a digital filtering process. An oversampling converter will usually carry out its measurements at an extremely high sampling frequency.

These are also known as *delta-sigma* A/D converters. They are new and they are hot.

The theory here is that the only tiny thing wrong with a one bit A/D is that its quantization noise is totally gruesome. By taking that quantization noise and spreading it out over a much wider bandwidth than the input signal and by then rejecting most of the noise with a filtering process, you can actually reduce the quantization noise to well below that of a 16-bit converter!

The *Crystal Semiconductor* folks are a leading developer of all these exciting new low cost oversampling converters.

A fairly good background book on A/D conversion in general is *Analog to Digital Conversion*, now available from *Analog Devices* for $32. Some of the fundamentals of computer A/D interface appear in my *Micro Cookbooks*, volumes I and II.

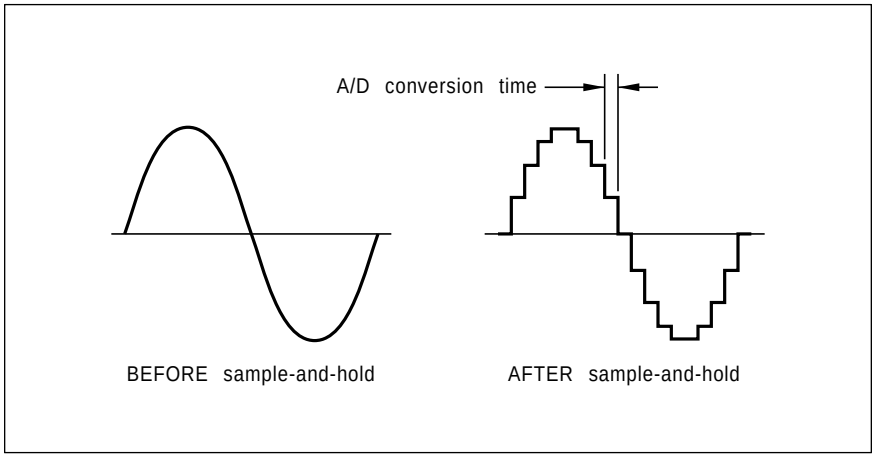


Fig. 3 – A sample and hold is needed to hold the analog input signal constant during the conversion time, or serious errors are certain to result.

The Rest of the Story

Unfortunately, though, your A/D converter chip will only be a tiny part of the hardware you'll really need to do an A/D conversion. Figure one shows you some of the rude suprises you have to work around to get a complete analog to digital conversion system up and running.

You'll first need some input *signal conditioning*. This will first accept the input signal and then amplify it enough so that its expected maximum value will match the converter's internal reference voltage.

Signal conditioning can also do such things as subtracting out an offset value, filtering, rejection of noise, temp compensation, or calibration.

The latest of the A/D converter chips will allow you to use lower or floating point reference voltages or else can provide enough bits that you might work at reduced resolution and are able to end up with useful results. Nonetheless, signal conditioning is a very sticky design area.

After you do all your initial signal conditioning, you *must* provide an *anti-aliasing* filter, and a darn good one. There is a fundamental rule that says that your A/D converter must *never* be fed any signal that is greater than *one-half* of its sampling frequency. Watch this detail.

Figure two shows you just what an *alias* is and how it gets created. Say you were on a long commuter airline flight and very sleepy. You briefly open your eyes and see a green service truck on the runway. You fall asleep, and later wake up an hour later at a new airport. This time the green service truck is ten feet further along. You repeat the process a third time, and now, the green truck is yet another ten feet further away. You then wrongly conclude that the green truck is traveling at ten feet per hour.

In exactly the same manner, an *alias* gets created if you sample any frequency near the sample rate of an A/D converter. For instance, if you do use a 40,000 Hertz sample rate and then sample a 40,100 Hertz signal,

you will apparently get a 100 Hertz signal digitized that you simply can not tell from a real 100 Hertz signal. This is an alias, and you absolutely must *never* let this happen.

One big advantage of all the new oversampling converters is that the anti-aliasing filter is both simpler and cheaper to build.

After filtering, you normally must do a *sample and hold*, as shown in figure three. If your input signal is allowed to change during the measurement interval, you can get wild inaccuracies since you will end up measuring a different amplitude at the end than you were at the start.

The sample and hold is normally done using an electronic switch that charges up a capacitor during your sampling, or the *aperture time*. The charge is held during the time your conversion gets completed.

At high resolutions, the penalty for omitting a sample and hold is severe. Figure four shows you the changes in the full accuracy frequency response you will get with or without using a sample and hold.

Fortunately, several of the newer chips do provide their own internal sample and hold circuits. But you will have to be absolutely certain you understand what the sampling process is and exactly how it works.

Your actual A/D converter follows your input conditioning, your anti-aliasing, and your sample and hold. This final circuit area is often the least of your problems.

Along the bottom, we also have shown you some *guarding* and *shielding*. It is trivially easy to let digital noise and power line hum totally trash out any accuracy from your A/D system. Ferinstance, a typical hacker digital circuit will be very lucky to hold the digital logic ground noise down below 300,000 microvolts.

On a typical 16-bit A/D converter circuit, any input noise greater than 15 microvolts or so might bobble the bits and give you all sorts of nasty jitter and errors.

If so much as a hint of a whiff of a few of the fumes of the ground noise ends up referenced to the input of your high resolution A/D, then all is lost. History. Gone forever.

Proper grounding and shielding techniques, including the full use of ground planes, guarding, and careful seperation of digital and analog grounds, are an absolute must.

number of bits	max frequency WITH a S/H	max frequency WITHOUT a S/H	speed penalty WITHOUT a S/H
2	20,000	3120	13
4	20,000	795	50
6	20,000	199	201
8	20,000	50	804
10	20,000	12	3216
12	20,000	3.1	12,868
14	20,000	0.8	57,472
16	20,000	0.2	205,887

Fig. 4 – A ridiculously severe speed penalty must be paid if you omit the sample and hold from your A/D converter. The examples here are for a 40 kHz conversion rate.

It is all part of the black art of analog circuit design.

The bottom line? Unless you have successfully gotten a low resolution, low speed A/D converter to operate, there is not a snowballs chance in a rather umpleasant locale that you will ever be able to accomplish anything at higher speeds and resolutions.

So, as one initial prequalification entrance exam that you have to pass before you could even think about doing any fancy A/D stuff, figure five is an ancient 8-channel 8-bit A/D circuit that you can build and test. The chip is available from either *National* or *Analog Devices* for a few dollars. It will interface simply with most any parallel port on nearly any microcomputer.

New A/D Chips

What are the new A/D chips and where can you get them? Last month we looked at the LTC1092 10-bit chip from the *Linear Technology* people. There is a fancier big brother to this device called the LTC1090 that does include multiple channels, adjustable formatting, and lots of other goodies.

The big breakthroughs in the new oversampling A/D chips are taking place over at *Crystal Semiconductor*. In particular, check out their instrument CS-5501 and their hi-fi audio CSZ-5116. These are both full 16-bit chips. And at insanely low prices.

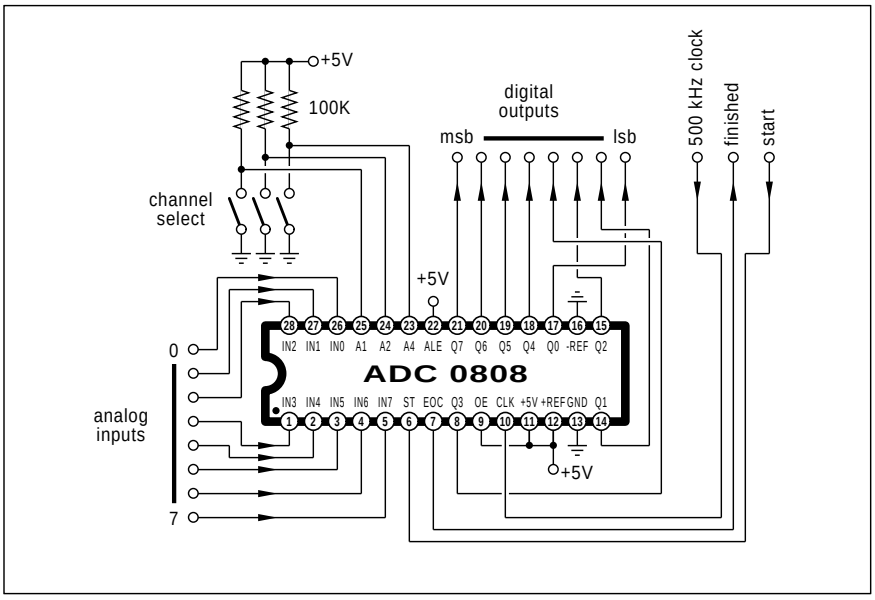


Fig. 5 – This older 8-bit, 8-channel A/D converter is very easy to interface to any parallel input port on most any personal computer.

The largest supplier of A/D converters to all those Japanese CD audio manufacturers is *Burr Brown*.

Texas Instruments has announced a new combined 14-bit telephone speed A/D and D/A for $26. It's intended for digital signal processing, but should also be an absolutely outstanding hacker chip. But half a dozen very expensive phone calls have proven this to be pure vaporware, at least for now. Let me know if you get one.

For video speeds, *Samsung* has a dozen different combined 8-bit A/D and 10-bit D/A chips. A KVS3110N-7 should be a good starting point for video hacking.

Other useful sources of video rate A/D converters do include *NEC*, *RCA*, *Texas Instruments*, and *Motorola*.

Finding Names and Numbers

How do you find out where to buy a *Maxim* integrated circuit? Or how do you get a *National Semiconductor* data sheet? Who makes solid state gyroscopes? Inclinometers? Thermoelectric coolers?

Naturally, you start with our own *Names and Numbers* section, and by reading all our *Radio Electronics* ads. But where to from there?

Let us begin with the only electronic directory that I actually pay cash for out of my own pocket. This one is the *Electronic Industry Telephone Directory*, and costs $40 per year from *Harris Publishing*.

An excellent list of many local distributors for electronic goodies will appear monthly in the *E. E. Times* magazine. But for some very strange reason, this otherwise great list seems to be strictly limited to their current advertisers.

Most electronic trade journals publish yearly directories that are extremely useful for pinning down names and numbers. I especially like the *Gold Book* from *Electronic Design*, the fine *Electronic's Buyers Guide* from *Electronics*, and that *EEM Master* by *Electronic Products*.

Various "focus" tech articles in *EDN* are also quite handy reference sources for names and numbers. And so are the ones in *Electronic Design* and *Electronic Component News*.

You can get a list of all of the trade journals from that *Uhlricht's Periodicals Dictionary* over on the reference shelf at your local library. Also at your favorite library should be the *Thomas Registry of Manufacturers*, and possibly even the *Electronic Represenatives Association (ERA) Directory*.

Asking for help from an engineer or a technician working for a larger electronics company will sometimes work, as might a ham radio operator, our technical helpline, the editor of a trade journal, or an electronic BBS.

Naturally, it is best to build up your library of the useful names and numbers ahead of time, rather than waiting until you'll desperately need some hard-to-get part. Your personal resource library should always be the first place to check.

Synchronous Inverters

I've been getting a lot of calls and letters from hardware hackers who have heard somewhere that, if you have a few solar panels or some other alternate energy source up, then your local power company is required by law to purchase all of your surplus power off you.

Well, in this day and age, most of the power companies are reasonably enlightened and often will be most happy to buy power from nearly any alternate energy source that is both local and and reliable.

But there are several very big gotchas here. Enormous even.

First, a power company will sell power to you at retail and buy it back from you at their wholesale *avoided cost*. Avoided cost is the price of the most expensive power that they are currently buying or generating. Thus, you do not simply swap energy, since one of their kilowatt hours may be worth five or more of yours.

Secondly, a very special device known as a *synchronous inverter* is needed to meter your energy back into the power line. As figure six shows us, a waveform is carefully crafted that feeds your power back in phase with your existing AC line waveforms. This gets sticky fast.

Synchronous inverters and all of the metering that goes with them are not cheap. The bottom line is an economic one. The time value of the money used to pay for the synchronous inverter and all of its metering will often insanely exceed the total value of all the power you are able to generate. Ever.

Thus, many smaller solar power installations are *never* able to reach a cost breakeven, let alone produce a profit. But I certainly encourage all of your dedicated hackers to keep on trying. The situation is certain to improve in the future.

The best sources of design and supplier information on synchronous inverters seem to be in several rather expensive trade journals. Visit a large technical library and see if they have back issues of *Solar Age*, *Solar Energy*, *Solar and Wind Technology*, or, on a more practical side, *Solar Engineering and Contracting*.

Unfortunately, many of these great solar and alternate energy resources have recently ceased most of their operations. Which is a rather sad commentary in and by itself.

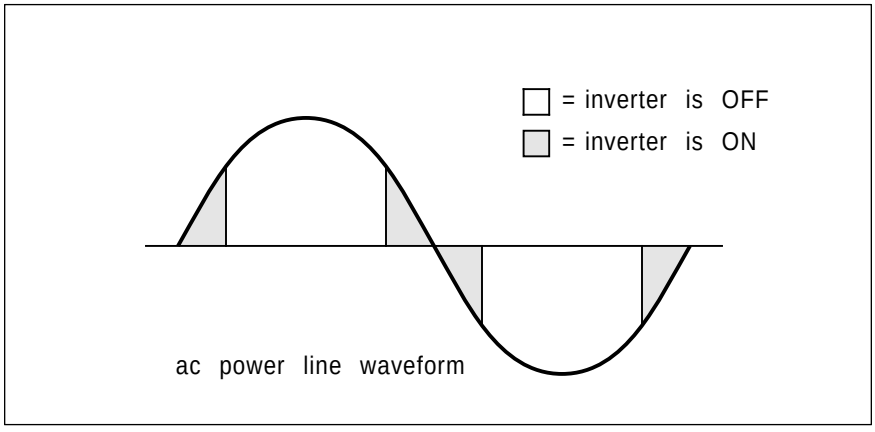


Fig. 6 – A syncrhronous inverter can be used to feed surplus energy from a solar panel or other alternate energy source back into the power line. Here is one possible waveform.

Don Lancaster's

Hardware Hacker

Patents and patenting
The LAN of the eighties
Hacking the handicapped
A new pressure transducer
Pressure measurement basics

October, 1988

Several helpline callers have asked just how you can go about accurately measuring the cryogenic temperatures involved with superconductor experiments. Ordinary thermometers will obviously not work.

A plain old silicon diode could be used, provided you can find one with a package that can safely handle the liquid nitrogen temperatures without cracking. Since the forward drop of a silicon diode at a constant current is a measurable function of the temperature, you can read the voltage across the diode with a digital voltmeter to get the temperature.

Silicon cryogenic temperature sensors are also available. One source is *Omega*. These folks also have an outstanding collection of data books and catalogs on such products as sensors for temperature, pressure, ph, humidity, strain, conductivity, and related tech books and software.

But do note that most of Omega's products are premium ones that command premium prices.

Several of the other sources of low temperature sensors do advertise regularly in that *Measurements and Control* trade journal. This is a great source for sensor and transducer info.

Let's start off with a look at . . .

Patents and Patenting

I have received several calls and letters this week that drive home the expensive, energy wasting, and time-consuming misconceptions that many hackers now have over patents and patenting. We'll start off with the one word bottom line involving any patents for hardware hackers 1 *don't!* Don't even think about it. Ever.

Three different helpline callers are apparently in the process of getting patents on three ideas that each have a century of totally obvious prior art involved with them. They are all also readily available as off-the-shelf products. One is a flourescent lamp, the second an electrolytic level, and the third is a capacitance microphone.

If a Las Vegas casino manager had the gross effrontery to offer the same odds the patent office does, he would get run out of town on a rail. Your state lottery is a far better investment than a patent.

Fact: Not one single patent in one hundred will *ever* show *any* positive cash flow. Many studies verify this.

Fact: Not one single patent in one thousand is solid enough that it cannot either be invalidated or severely reduced in value through a diligent enough search for prior art in obscure enough places.

Fact: A patent does not in any way prevent others from stealing your ideas. All it does is give you the right to sue someone. Once patented, any individual anywhere in the world can get a copy of your ideas simply by reading your patent.

Fact: In patent litigation cases, the side with the most resources will almost invariably win. Even with a totally bulletproof patent, the legal process can be made so drawn out and so expensive that the winner will lose, and vice versa.

The conventional wisdom goes something like this: First, get an idea. Second, patent it. Third, sell the idea to a large company. Well, in the real world, each one of these three concepts is "patently" absurd.

I would like to be able to report to you that ideas are still worth a dime a

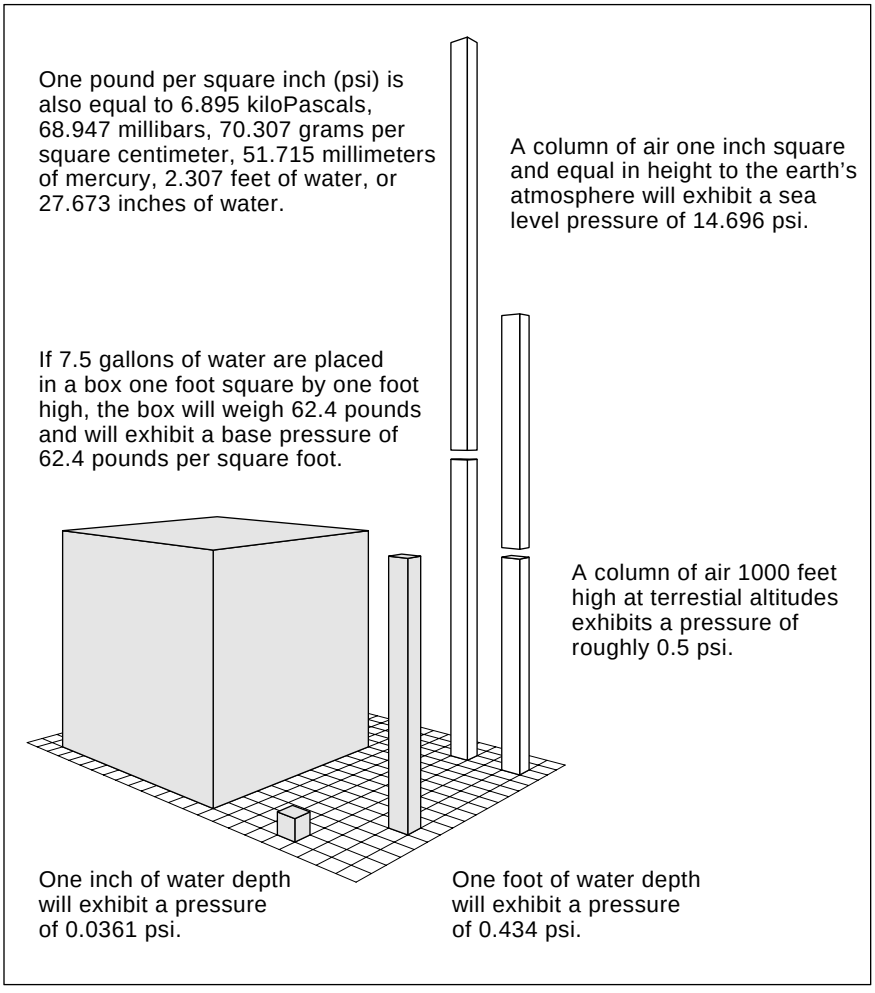


Fig. 1 – Here are some of the fundamentals behind pressure measurement.

bale in ten bale lots. It is only when an idea is both converted into a form that people can use and in fact are actually and aggressively using it, that the idea gains any value.

Many hackers seeking patents do not bother to search the literature, and most especially all of the trade journals, to find out ahead of time what the competition is, which of the products already exist, and what the demand is in their area. Some will even totally ignore all of the fundamental physical laws and the other constraints that lie behind their ideas.

Most larger companies are not in the least interested in new products and ideas. It is far simpler for them to "steal the plans" and go with an established product. They feel that the pioneers are the ones with all the arrows in their backs. As an obvious example, not one of those traditional dino computer firms even entered the personal computer market until long after it was thoroughly proven.

And then they did so with some very conservative and "me too" products. Even at that, many of them ended up by failing miserably.

Further, many larger companies will positively refuse to *ever* look at *any* submitted patent or idea, since it opens them up to all sorts of "you stole my idea!" litigation hassles, and might compromise in-house research already in progress.

So, by all means continue all of your hacking, and by all means do continue all your experimenting and developing of ideas and products.

But, for most hackers most of the time, I personally just cannot see any point whatsoever in seeking out all of those time, dollar, and psychic energy sinks that the patent process rep- resents today.

Measuring Pressure

The single quantity price of solid state pressure transducers has now dropped to under $9, opening a whole new world of hacker opportunities. Besides the traditional suppliers of *Motorola* and *Micro Switch*, newer outfits that include *SenSym*, *IC Sensors*, and *Nova Sensor* now offer high volume and low cost pressure sensing products off the shelf.

Before we look into a typical low cost sensor and its uses, let's review some of the fundamentals.

Pressure is force per unit area, and often gets measured as *pounds per square inch* (PSI) or in similar units. Figure one shows us some important pressure relationships.

If you take a box that is one foot square by one foot high and fill it with water, it will weigh 62.4 pounds and will thus exhibit a total pressure over its bottom of 62.4 pounds per square foot. It will take a tad under 7.5 gallons of water to do this.

Now, since there are 144 square inches per square foot, one foot of water head is apparently equal to 62.4/144 = 0.434 PSI. If your city water tower is full and a hundred feet high, it will produce 43.4 PSI of static line pressure.

The lower pressures, such as those associated with air conditioning and blowers, are sometimes measured in *inches of water*. An inch of water is 1/12th of a foot of water, and is equal to 0.0361 PSI.

Turning to air instead of water, if you take a column of air that is one square inch in cross section and equal to the entire atmosphere in height, it will exhibit a pressure at sea level of 14.696 PSI. While the pressure-vs-altitude curve is nonlinear, you will get a pressure drop of roughly 0.5 PSI per thousand feet of elevation.

A terrestial altimeter having a one foot resolution would have to be able to resolve 0.0005 PSI. Digitally, this would take a minimum of 12 bits of resolution, or, more realistically, between 14 and 16 bits.

Atmospheric pressure will also vary with the weather. A *Barometer* is a pressure transducer that has been optimized for weather prediction use.

As figure two shows us, there are three fundamentally different ways of measuring pressure. A *Relative* pressure measurement will measure the difference in pressure between the two liquid or air inputs. Nearly all of today's solid state pressure transducers start out by measuring relative pressure.

Absolute pressure measurements are made by comparing one pressure input against a nearly perfect vacuum or some other precision reference. A relative pressure transducer is converted into an absolute one by evacuating and sealing one input side.

Gauge pressure will get measured against the *ambient*, or atmospheric pressure that happens to exist here and now. The pressure gauge on a water system measures, of all things, gauge pressure. A relative transducer is converted into a gauge transducer by leaving one of its inputs open.

Two of those traditional pressure transducers are the *Bourdon gauge* and the *aneroid barometer*.

A Bourdon gauge can be built by sealing a pipe end and spirialing it. As the pressure increases or decreases, the spiral will tighten or loosen, moving the sealed end of the pipe. Some of the New Year's Eve party favors work on the same principle.

An aneroid barometer consists of a sealed bellows having one fixed end. Should the external pressure change, the bellows will expand or contract,

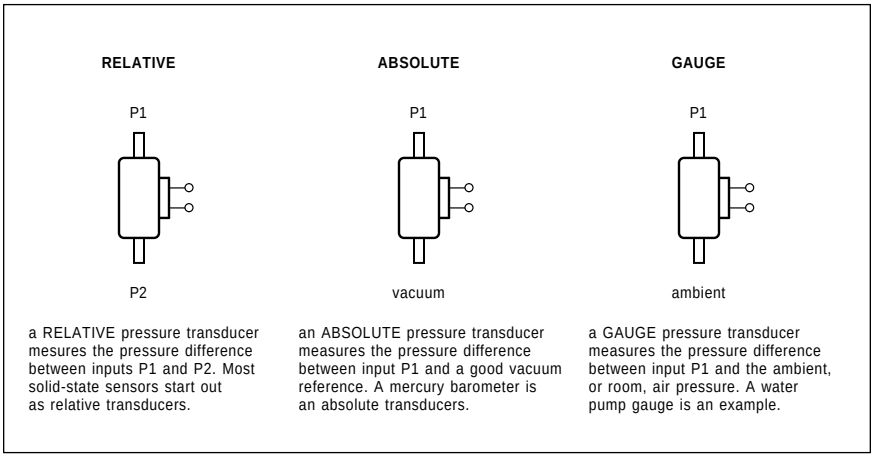


Fig. 2 – There are three fundamentally different types of pressure sensors. Most of the new solid state transducers start out as relative devices.

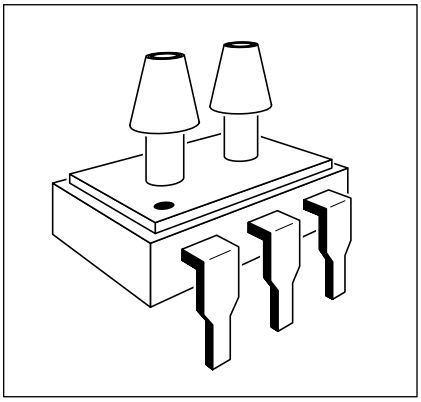


Fig. 3 – A Novasensor NPS-030-D1 is a 5 psi and $9 relative pressure transducer that comes packaged in a plastic 6 pin mini-DIP.

thus moving its other end.

Both of these do have some serious shortcomings. Since each is a mechanical system, you'll get *stiction* that prevents very small motions, and a *hysteresis* where you do not return to exactly the same position each time. The *linearity* is also not all that great, especially for large changes.

Most of these newer solid state transducers consist of a thin silicon diaphram that supports a strain gauge resistor bridge. One pressure port accesses each side of the diaphram. As the relative pressure changes, the diaphram will flex, thus changing all your resistance values and giving you a resistance change that can produce an output voltage that is in turn proportional to the overall relative pressure difference.

The output levels are typically 100 millivolts full scale, so some amplification and other conditioning is usually needed for real-world uses. Besides this, various temperature and offset compensation schemes also will usually need to be used. As we saw last month, the latest of the new A/D converters are now capaable of directly accepting an unconditioned transducer signal as an input.

Silicon is an very linear material that is easily and precisely machined. The linearity, hysteresis, and stiction of silicon pressure transducers are often ridiculously better than those earlier mechanical systems. Since all of the structures involved are now insanely smaller, your final frequency response is also greatly improved.

So, what can you do with a cheap pressure transducer? Some obvious applications are altimeters, barometers, pressure gauges, air regulators, liquid level sensors, air conditioning and ventillation systems, fluidics, intrusion alarms, toys, auto emission controls, the blood pressure monitors, microphones, stream gauges, acoustic sensors, speaker enclosures, robotics, flowmeters, aerobic training aides, sonar, new musical instruments, and weighing scales.

But, how about you tellling me instead? For this month's contest, just dream up some off-the-wall use for a cheap pressure transducer. A paper design will be just fine. We'll have all the usual *Incredible Secret Money Machine* prizes, including one all-expense paid (FOB Thatcher, AZ) *tinaja quest* for two for the very best entry of them all.

As per usual, send your all entries directly to me, and not to the *Radio-Electronics* editorial offices.

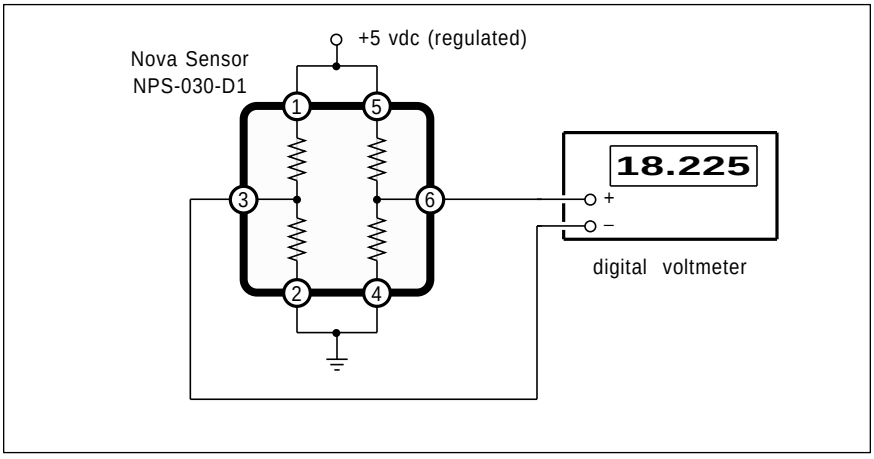


Fig. 4 – This simple circuit will get you started experimenting with the new solid state pressure transducers. This sensor is rated at a relative 0-5 PSI.

A new Pressure Sensor

The *Nova Sensor* people recently had a factory direct, $9 in singles sale on their NPS-030-D1 and a few other pressure sensors. Figure three shows us this jewel, which is packaged in a six pin mini-dip with two pipes out the top. The range is 0-5 PSI.

Figure four shows you a good test circuit, which is a plain old resistive Wheatstone Bridge. All you need is a five volt regulated supply and a good digital voltmeter. When you blow or suck into a hose connected to one of the pipes, the pressure should change by twenty millivolts or so, corresponding to a pressure difference of 1 PSI or so. Your full scale sensitivity should be somewhere around 100 millivolts for a 5 PSI difference.

If you can skag a high precision DVM that can resolve down to tens of microvolts, pinch off a rather short hose connected to one of the pipes, and see if you can't get a 10 microvolt change for each foot you raise or lower the sensor.

In a real-world application, it will be very tricky indeed to gain better than a fifty foot altimeter accuracy. But please let me know if you can do this, for I know some cave mappers that sure would like to get their hands on an affordable and rugged one-foot resolution survey altimeter.

Several of the altimetry measurement problems that are involved do appear in the *SenSym* data book. A free pressure calculating slide rule is included with each data book.

By the way, some low cost rubber hoses in hacker lengths are available from *Hygenic Manufacturing*. Do be sure to have the actual data sheet and ap notes on hand whenever you are using any pressure transducer.

Each transducer is measured at the factory and gets supplied with a list of compensation resistors that are needed for the best temperature performance. Figure five shows us how these will get used. It is up to you to provide these resistors by yourself. Usually, either R1 or R2 will be a short circuit, and either R3 or R4 will be an open, so a maximum of three compensating resistors are all that are normally needed.

The LAN of the Eighties

There sure is lots of interest these days in LAN's, short for *local area networks*. Many of these are poorly performing, insanely expensive, or else grossly limiting in one way or another. But one LAN is clearly head and shoulders above all of the others. So much so, that I like to call it the *LAN of the eighties*.

The LAN of the eighties is a simple token ring loop. It requires only one single wire between all your stations. Your wire need not be shielded or twisted pair, and even *bare* wire has been used in many of those tens of thousands of installations used today.

The LAN loop can be ten or more miles long. While only a few dozen servers is the norm, many hundreds can be installed. In turn, each server node normally is able to handle up to several hundred individual users.

With the LAN of the eighties, each node uses a unique i.d. in a collision avoidance, token passing protocol. The node first checks to see if other traffic is present. If not, its private uniquely coded packet gets transmitted. Each packet is then repeated several times to get the best possible error correction.

Each LAN node is also sophisticated enough that it continuously measures the network's signal to noise ratio. Should any communications problems develop, then an alternate signalling route will automatically get selected.

Each node is extremely rugged and requires little maintenence. All of the nodes use zero electrical input power, by substituting one incredibly ingeneous and kinetic energy based power transfer mechanism.

A companion streaming tape drive is usually included with the LAN of the eighties. It uses quite low cost media is normally used to continuously and permanantly record any and all traffic. Thus any message can be replayed at any time.

On the LAN of the eighties, the operator training is extremely fast and ridiculously simple. Even a user in a very high stress environment can master the entire LAN workings in approximately five seconds, since the entire system is hardware based. Yes, even the boss can learn to use it.

The LAN of the eighties has been thoroughly tested and debugged. So much so that the total number of LAN user hours to date does ridiculously exceed that of *all* of those other LAN networking schemes combined.

Yes, this network is so good that it's clearly the LAN of the eighties.

The *eighteen* eighties!

I am, of course, talking about the *Gamewell* fire alarm telegraph system, otherwise known as that old mangy red box scunging away on the pole down the street. Patented over a century ago. Deja Vu, anyone?

Hacking the Handicapped

The personal computer has been the great equalizer for all the handicapped, and we sure get lots of help line calls on this topic. Table I lists many of the organizations and other resources involving therapy, special education, and whatever.

Both *Apple* and *Tandy* do have excellent special education contacts and resources available, as do many ham radio clubs.

New Tech Literature

All those field programmable gate arrays and the similar complex logic modules are starting to drop in price. These go far beyond all your usual *EPROM* or *EPLA* chips and literally let you build your own fully custom integrated circuits.

Three good resources to get you started are the *Exel Data Book*, that *Xilinx Programmable Gate Array Design Handbook*, plus that *Monolithic Memories LCA* Applications Book.

R & D Electronics is a surplus outfit having some interesting products and excellent prices. These include microwave amplifiers at $2.50 each and steppers as low as $4.95. Ask for catalog #10.

We sure get a lot of requests for blue light emitting diodes. It turns out that there are several fundamental physical laws that make blue LED's rather tricky to build. You have to go to highly exotic and hard-to-process materials, such as silicon carbide, in order to do the job.

So, yes, you can now run out and buy a blue LED. And the price is only a mere several hundred times higher than a green one. But if you do really and truely want a blue LED for instrument calibration, colorimetry, or whatever, *Seimens* will be happy to sell you their standard size and shape LBD5410. The peak wavelength will center around 480 nanometers. The usual brightness is 6 mcd.

If you are into just about any sort of modelmaking, exhibit, or display activities, be sure and investigate the *Fomebords* people. Start with their *Pumping Foam* catalog that lists all

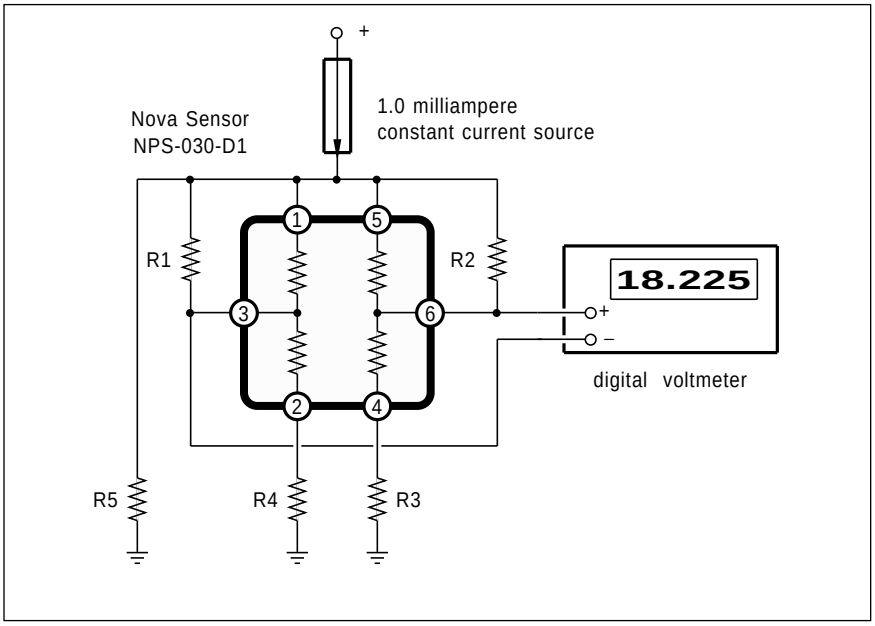


Fig. 5 – Extra resistors can be provided for temperature compensation and for span adjustments. Correct values are specified for each sensor.

types of interesting and totally mind-blowing materials.

Analog Devices does have their expanded and revised *Analog-Digital Conversion Handbook* out. This well written hardbound text is a cut above your typical in-house "official company line" publications. It is worth the $32 price. You can also get a free subscription to their *Analog Dialog* house organ by contacting Cammy O'Brian per the names and numbers at the end of this volume.

There is also a new *Linear and Conversion Applications Handbook* available from the *Precision Monolithics* people. While the ap notes are aimed primarily at all their premium op-amps, there's a lot of good info here that can be applied to most any old bargain op-amp.

For the latest in power supply design, check into the *Power Supply Circuits Handbook* by *Maxim*, the *Lambda Semiconductor Applications Handbook*, and then subscribe to the free *Powerconversion* trade journal.

The *Intersil Application Handbook* has got bunches of goodies on data acquisition and A/D conversion in it. From *SGS*, an L-296 switching regulator evaluation kit. This includes the circuit board and two chips needed for a 4 amp, 5 to 40 volt dc step-down switching regulator. You still have to wind your own coil. The kit is free on a letterhead request.

Two distributor catalogs came in recently, one from *Newark*, a full "old line" electronics distributor, and one from *Mouser*, having mostly foreign components at outstanding prices and low minimums. A surplus catalog from *Marlin Jones* including super cheap pricing on ultrasonics, lasers, digital display kits, robotics, steppers, and such.

From *Texas Instruments*, a LSI Logic Data Book. Several intriguing new devices here include a memory mapper, a barrel shifter, read-back latches, shaft encoder interfaces, and nearly 200 pages of ap notes.

From *AESAR*, another catalog of exotic metals and elements at exotic prices. For some strange reason, none of these exotic metals houses offer six inch plutonium spheres. I guess it is because this particular product can give you a totally unfair advantage in lawn bowling.

Turning to some of my own products, if you want to create and sell your own hacker products or ideas, be sure to check out all the tested and workable insider stuff that's in my underground bestselling *Incredible Secret Money Machine* book.

If you are at all interested in any *Apple* computing, be certain to check into both volumes of my *Enhancing your Apple IIe*, an *AppleWriter Cookbook*, and the classic *Apple Assembly Cookbook*. By one of those absolutely astounding coincidences, I do appear to have several autographed copies on hand here.

As I've mentioned a time or two before, I have got a sister column to this one over in *Computer Shopper* that is heavily into desktop publishing, *PostScript* programming, Apple computing, *tinaja questing*, and the usual off-the wall topics. A sampler of most of the previous columns are now available as my *Ask the Guru* reprints. Included is lots of top secret stuff that simply is not available elsewhere. Let's hear from you.

Apple Special Education
20525 Mariani Avenue 36-M
Cupertino, CA 95014
(408) 996-1010

Children's Resource Center
1056 E 19th Avenue
Denver, CO 80218
(303) 861-6633

Closing the Gap, Inc.
PO Box 68
Henderson, MN 56044
(612) 248-3294

Communication Resources
3201 Marshall Road
Kettering, OH 45429
(513) 298-0803

Computer Access Center
2425 16th Street Room 23
Santa Monica, CA 90405
(213) 450-8827

Computer CITE
215 East New Hampshire
Orlando, FL 32084
(305) 299-5000

Children's Computer Group
2095 Rose Street
Berkeley, CA 94709
(415) 841-3224

Disabled Children's Group
1146 South Third Street
Louisville, KY 40203
(502) 584-1239

Disabled Technical Center
5759 Hedgehaven Court
Las Vegas, NV 89120
(702) 382-3358

Handi-Ham System
3915 Golden Valley Road
Golden Valley, MN 55422
(612) 588-0811

National Braille Press
88 Saint Stephen Street
Boston, MA 02115
(617) 266-6160

Pacer Center
4826 Chicago Ave South
Minneapolis, MN 55417
(612) 827-2966

SpecialLink
2512 Canterbury Avenue
Cincinnati, OH 45212
(513) 531-9233

Special Technical Center
Route 4, 433 East Lafayette
Jackson, TN 38301
(901) 423-9058

Special Technology Center
535 Race St, Suite 220
San Jose, CA 95126
(408) 288-5010

SuperGroup Evaluation
4129 Beaujolais
Kenner, LA 70065
(504) 561-8713

Technical Access Center
183 Lake Avenue
Newton, MA 02159
(617) 969-4279

Technical Assistance
1950 West Roosevelt Road
Chicago, IL 60608
(312) 421-3373

Technology Resources
3023 Canterbury
Salina, KS 67401
(913) 827-0301

Trace Development Center
1500 Highland Avenue
Madison, WI 53705
(608) 262-6966

Table I – Some technical resources for the handicapped.

Don Lancaster's

Hardware Hacker

November, 1988

A cheap color fuser mod
More on the $10 NaviCube
Omnicrom and Kroy Kolor
Television on a RGB monitor
Industrial and trade resources

I have found several additional sources for all those telephone coupling transformers that will be needed for the data access arrangement circuits we looked at a few columns back.

In particular, check out the TXTS transformer from *All Electronics* at $2.50 each, or any of the bunches of different offerings from the *PREM Magnetics* folks.

A new transformerless telephone interface did appear way back in the October 81 issue of *QST*. The circuit shown ended up rather complex. It also had to be custom adjusted to suit each individual phone line.

Some details on an all-Canadian approach to our $10 Navicube are now available from Richard Langley of the *Geodetic Research Laboratory*. They also have some great new publications on navigation satellite positioning systems available.

Apparently the all time numero uno super whiz bang expert of all the earlier Navicube stuff is Doug Garner at NASA. Check out all his superb construction projects found in *Sport Aviation* magazine, starting in the late 1970's.

Of all the Hardware Hacker topics ever, the $10 Navicube coverage sure produced the greatest number of the most interesting phone calls and letters from some of the most creative hackers around.

More on the Navicube drama as it unfolds.

As per usual, this is your column and you can get technical help and off-the-wall networking by using the *Need Help?* and the *Names and Numbers* sections you'll find at the end of this volume.

This month, we'll look at some graphic art electronics . . .

Omnicrom and Kroy Kolor

For years, I've had a back-burner project going. The idea was to take an ordinary Xerox copy and send it through a magic machine where real ink would somehow stick only where the toner first existed.

Obvious uses would be to get truly dense blacks, to be able to create a "litho" quality image for printed circuits, overheads, for your electronic artwork, to gain total color options, and to provide a durable "raised ink" thermography process, for letterheads, for custom business cards and even for printing in Braille.

It turned out that an English outfit by the name of *Omnicrom* beat me to the punch. As figure one shows us, Omnicrom reasoned that toner was really a mixture of black stuff and hot glue. You could think of a copy as a piece of paper that had hot glue selectively located only where you really wanted it.

By putting a dry ink based carrier in contact with the Xerox copy and applying heat and pressure, the toner would remelt and grab the dry ink off the carrier sheet.

Presto. Your instant conversion of a copier or laser printed output into brilliant metallics or bright mattes, silvers, golds, a solid black, and even some pearl effects.

Along with the unique shiny high gloss varnish and even a true laminating for those scuff-resistant menus or book covers.

As a bonus, your carrier sheet can also become an "instant negative", as used for such applications as overhead transparencies. If you wanted to, you could even reuse any left over portion of any carrier as often as you liked, trading cost for labor.

But there were serious problems. The Omnicrom people were Brits and thus predictably and monumentally mismanaged all of their marketing efforts in the colonies. Their early materials were not all that reliable. Worst of all, they saw nothing unconscionable about the charging of over $1400 for the "fusion machine" that was really nothing but a pair of warm rollers that turned.

A few years ago, the *Kroy Kolor* people did become an Omnicrom licensee and dramatically improved all the materials, added more colors and options, and made them much easier to get. They also improved and modestly lowered the price of the fusion machines.

You can get some free evaluation samples just by calling Randy Bailey over at Kroy. They also do have lots of sign-building accessory kits and heavier printing stocks.

But, judging from the *Perrier* in all of their corporate birdbaths, Kroy appears to be a company of, by, and for Yuppies. "Low end user cost" just is not in their vocabulary. If you do

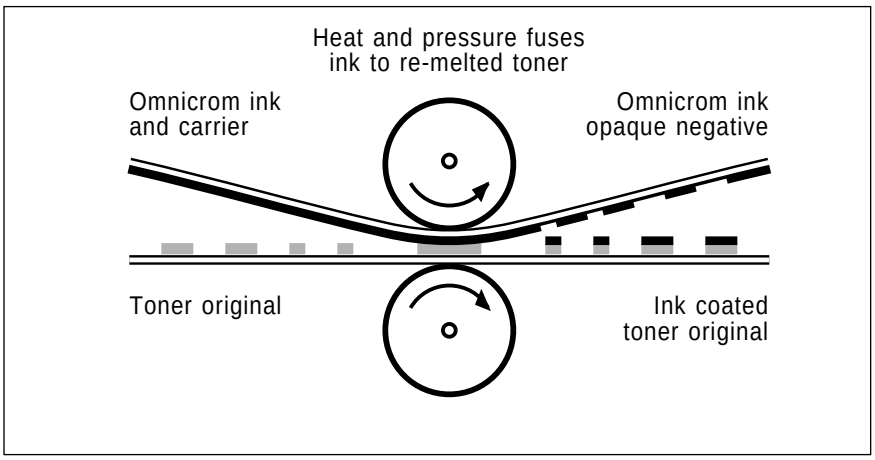


Fig. 1 – The Omnicrom process rapidly converts any toner based copier or laser printer image into full color in any of dozens of metallic, matte, or special effect shades. Kroy Sign Systems now licenses the British Omnicrom process under the US tradename of Kroy Kolor.

1 – Canon F21680 Fusion machine using a FH1-0576-01 temperature printed circuit card.

1 – 25K linear volume control
1 – 150K, 1/2 watt resistor
1 – Dialplate decal
1 – Dialplate decal overlay
1 – Push-on knob with pointer

Misc: 12 inches of red solid #22 wire; 12 inches of similar green wire; 12 inches of similar black wire; 8 inches of solder; two 3/8 inch volume control nuts; 1 flat volume control washer; 1 internal tooth volume control lockwasher.

Note: One source of the Canon fusion machines, parts kits, and modified and tested units is Arlin Shepard at Lazer Products, 12741 East Caley Avenue, Suite #130, Englewood CO, 80111. (303) 792-5277.

Fig. 2 – The parts required to modify a Canon F21680 fusion machine for variable temperature operation.

not own a BMW, they do not appear to want you as a customer.

It might still take a while before some genuine competition can drive the end user costs down to the nickel-per-sheet mass market range where they rightfully belong.

Kroy Kolor is a fantastically great product when and where that sixty cents or so per sheet cost could be justified. This product totally revolutionizes what you might do with a copier or laser printer. The sad thing is that it could do so much more if only it were sanely priced.

Meanwhile, though, the quest goes on for . . .

A Cheap Omnicrom Fuser

You do not need $1400 to use Kroy Kolor or Omnicrom. All you need is heat and pressure.

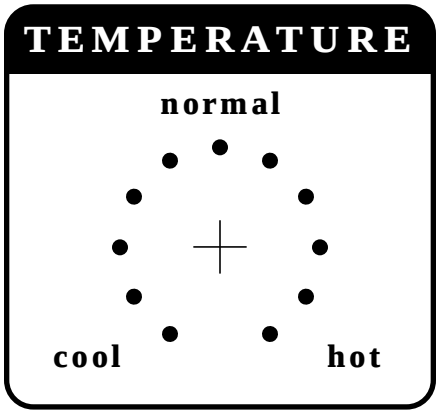


Fig. 3 – Full size artwork for the front panel decal.

For instance, a plain old iron and a muslin pressing cloth will do the job just fine. You can also use the existing fusion rollers inside your laser printer or copier, by making a second pass while manually feeding a blank page. The process works best with all the metallic colors. But, you might ocassionally get a misfeed, wrinkles, or dropouts. Sigh.

A few of the newest copiers are set up to directly use Kroy Kolor.

One trick that works well and dramatically drops the price is to use spot color. Ferinstance, on a letterhead, you tape a small piece of Kroy Kolor applied only to the logo and then run it back through the printer. Be sure to use a very low tack tape, such as the Scotch *Post-It Cover Up Tape*, that is usually available at your local office supply.

But there is a better way. It turns out there is a wondrously bizarre machine widely available today on the surplus market known as a *F21680 Canon Fuser Unit*.

Nobody (especially those *Canon* dealers!) had even the slightest idea what these machines were for or how to use them, so they were all dumped at fire sale prices. Rumor has it the machines were somehow involved in creating color overhead projection transparencies.

At any rate, the only differences between a real Omnicrom fusion machine and the Canon fuser unit is around 5:1 in cost and the fact that the stock Canon fuser machine was preset to a fixed and somewhat lower temperature.

Fortunately, only sixty cents worth of parts and twenty minutes of work will convert your Canon unit into a beast that actually will outperform the Omnicrom machine and do so at a tiny fraction of the cost.

The super rugged Canon unit gives better results due to a slower feeding speed and some self-cleaning roller wiper pads. It works especially good with the SX toner cartridges, such as from a LaserWriter NT or NTX.

The only little problem that I have found with the modified unit is that you have to trim your laminating film to a maximum width of 8-1/2 inches. The Kroy *Color Plus* fusion machine shares the same problem.

Figure two shows you a parts list for this mod. Figure three is the a full size replica of your new dial decal. Figure four gives you detailed instructions, while Figure five shows you where to position your decal on the front of the machine. Finally, Figure six is a pictorial for the mod.

The fusion unit does its thing by comparing the thermistor resistance against a fixed voltage reference. The modification lets you raise or lower the internal reference by sourcing or sinking a little extra current.

The temperature range is set by the new 150K resistor. A higher value *restricts* the range, while a lower one will *extend* it. A half-watt resistor did get chosen here because it is physically stronger than a quarter watt one.

Your checkout procedure is fairly simple. First, center your new temperature control and then apply the power. The panel LED should start blinking a dim green and the internal fusion lamp should come on. After one minute, the fusion lamp should go out and the LED should change to a bright and continuous green.

Advance the temperature control clockwise by one quarter of a turn. The fusion lamp should come on for three or four seconds and then shut itself back off.

Retard the temperature control fully counterclockwise and wait a few minutes. Eventually the fusion lamp should come back on for a few seconds. When the lamp goes back off, advance the control by one quarter

turn. The fusion lamp should go back on again for a few seconds and then shut itself down.

If all of these tests are passed, next center the temperature control and try a metallic Kroy Kolor sheet. Use a "normal" setting for metallic foils, a somewhat higher setting for the matte colors, or a slightly lower setting for the laminating film.

Here's another tip: If you run a toner copy through your machine in contact with a thin sheet of *mylar* or polyester film or by using an "empty" Kroy Kolor carrier, your copy will then *Bakerize*, giving you a far more durable, a blacker, and a semigloss finish. This is handy for such things as quick and dirty business cards, and is a zero cost process.

Among the other sources, surplus Canon fuser units are available from Arlin Shepard at *Lazer Products*.

Both modification kits and fully modified and tested units are also available, at a tiny fraction of the current cost of those real Omnicrom fusion machines.

Getting Plain Old Stuff

Besides all of the usual electronic components, all of you hardware hackers also need good sources of the plain old everyday things needed to develop all of your ideas to actually combine and then assemble all of the electronic components.

Things like tools and hardware, raw material stocks, electrical items, plastics, and all of those many other oddments that seem to go along with serious hacking.

I've found four very good sources for this sort of thing.

First, check into the *McMaster-Carr* supply people. See if you can't cop one of their 2000+ page catalogs that is jam packed with all the tools, materials, hardware, plastics, and just about everything else you might call "industrial" in nature.

Second is that really great *W.W. Granger* catalog, which covers pretty near everything electrical 1 for wire, pumps, motors, controls, accessories, and so on. While these folks have branches in most larger cities, you often may need a trade name and a tax stamp to be able to do business with them in some areas.

Third is *Small Parts*. Besides their mind-boggling stock of all robotic and electronic hardware, they also can custom cut metals and plastics for you in small quantities.

And, fourth, for plastics, look into the *United States Plastic Corp* who do have a very wide variety of plastic materials available.

If you have any similar "just stuff" favorites, how about letting me know so we can then share these resources with the others.

In fact, let's make a contest out of it. Your entry has to begin with the words "A great source for neat stuff is…." There will be all of those usual

( ) Verify that the unit to be modified is in fact a Canon F21680 machine and then unplug the line cord from the AC outlet.

( ) Remove the center lid by raising the green handle and removing the two black screws at the rear and the two silver screws on the inside. Be gentle!

( ) Remove the right cover by removing the two silver screws at the rear, the black screw at the right bottom, and the black screw at the front bottom. Again, be gentle!

( ) Cover the temperature decal with a similar sized clear self-stick overlay. Neatly trim the decal to just outside the black border.

( ) Clean the front of the right cover and apply the temperature decal so it is 3/8 of an inch in and 3/8 of an inch up from the lower lefthand corner. (See Figure five)

( ) Drill a 13/32 inch hole at the crosshairs on the temperature decal. This is easiest to do with a Vise Grip UNIBIT, but a pilot hole and reamer can be used instead. Deburr the hole.

( ) Mount the volume control in the hole. Use a nut and lockwasher behind the panel and a nut and flat washer in front of the panel, adjusting for the flushest possible mounting.

( ) Solder the 150K resistor to the center lug of the volume control, keeping the lead both reasonably short and mechanically strong. (See Figure six)

( ) Form a loop in the free end of the resistor and trim the lead. Strip 1/4 inch off of both ends of the green wire and solder one end to this resistor loop. (See Figure six)

( ) Strip 1/4 inch off both ends of the black wire and solder it to the leftmost lug of the volume control when viewed from the rear bottom. (See Figure six)

( ) Strip 1/4 inch off both ends of the red wire and solder it to the rightmost lug of the volume control when viewed from the rear bottom. (See Figure six)

( ) Twist all three wires tightly together for all but the last inch of their length.

( ) Unplug the black and white motor connector from the innermost circuit board. Unplug the two heavy red wires from the motor speed sensing power resistor.

( ) Remove the three large Phillips screws that hold the circuit boards in place. You may have to restrain the white circuit board spacers to keep them from turning when you do this.

( ) Slide the two circuit boards out where you can work on them. You may have to work up some slack in the yellow thermistor wires. Unplug the five pin black and blue connector.

( ) Verify that the yellow thermistor wires go to a FH1-0576-01 printed circuit board.

( ) Route the twisted black, red, and green wire between the motor starting capacitor and the motor control power triac. Then route it along the yellow wire, through the small hole, and over to the FH1-0576-01 printed circuit board.

( ) Loop and solder the black wire to the inside end of diode D303. (See Figure six)

( ) Loop and solder the green wire to the outside end of resistor R307.

( ) Loop and solder the red wire to the outside end of diode D304.

( ) Replace both circuit boards, the three large Phillips screws, the black and white motor connector, the two red power resistor wires, and the blue 5 pin connector. Redress the yellow thermistor leads back the way they were.

( ) Verify that the right cover can go back on without pinching any wires and that there are no wires anywhere near the large gear or other moving parts.

( ) Verify that all connectors and wires are now secure.

( ) Replace the right cover and the lid using the original screws.

( ) Press the knob onto the volume control shaft, being certain that the pointer points straight up to NORMAL when at the center of its rotation range.

( ) Refer to the text for the checkout procedure.

Fig. 4 – A surplus Canon fusion machine can replace an Omnicrom or a Kroy Kolor machine at a tiny fraction of the usual cost, after this fairly simple 60 cent modification is made.

Incredible Secret Money Machine books, along with an all-expense paid (FOB Thatcher, AZ) *tinaja quest* for two for the best entry of all.

If possible, do include a flyer or a catalog with your entry. You'll get extra points for especially obscure or off-the-wall sources. Please send the entries directly to me per the "Need Help?" box, and not to the *Radio-Electronics* editorial offices.

To get you started, here are a few more of my favorites . . .

Electronic Surplus Sources

I guess I've always been a surplus junkie, and have been buying bargain and odd lot mechanical and electronic stuff for longer than I care to remember. There's no better way to get hands on electronic experience at low cost than by adapting and later reworking your surplus components to meet your own needs.

My all time favorite surplus house has to be *Jerryco*. If not for their outrageous catalog, then for their wide variety and their bargain prices. They are not real strong in the electronic area, but they more than make up for it in unusual materials, mechanisms, motors, electromechanicals, far out goodies, and such.

For the old time, old line military WWII surplus electronics, *Fair Radio Sales* is an excellent choice. One of the first surplus items I ever bought was from them. It was a complete APN-1 radar altimiter for $2.95. I sure was surpised when the *Railway Express* (Uh 1 I guess I may have been at this for a while) charges were a budget breaking $8. During college days, I earned some quick cash by buying surplus electronic castings from these folks and then converting them into far out decorator lamps.

The yuppie reign of terror has mercifully ended over at *Edmund Scientific*. In fact, there is not one single *Perrier*-filled birdbath in their entire catalog these days. While they are the merest shadow of their former selves, they have a fairly wide selection of optics, pneumatics, and mechanics on hand.

For "raw iron" in the form of transformers, motors, actuators, clutches, hydraulics, and such, *C & H Sales* has some fine offerings. No robotics hacker can afford to miss out on their interesting catalogs.

While not strictly surplus, a fine source of low cost electronic components is *Mouser Electronics*. They have a lot of brand new stuff that is super hard to find elsewhere.

And those are pretty much my favorites. Besides these, you'll find *Surplus Traders* for cable tv stuff and assorted Canadian surplus. While fairly pricey, *Herbach and Rademan* occasionally have some real bargains. They are very strong into broadcast television surplus. *Marvin Jones* will typically have outstanding electronic whatevers at very low prices. Good old *BNF Enterprises* have bargain priced and assorted floor sweepings available, with an occasional gem buried in their big tabloid catalogs. The prices are so low that "you buys your ticket and takes your chance".

Some newer outfits to look into include *Circuit Specialists*, *American Design Components*, and the *Electro-value International* people.

Finally, of course, there are the many fine advertisers right here in *Radio Electronics*, some of whom I just have not yet had the chance to fully check out.

Receiving TV on a RGB Monitor

I've gotten a bunch of calls on this recently. You've just spent big bucks on a high quality RGB color monitor for your computer, and realized that it sure would be nice to be able to receive cable or off- the-air tv onto it to justify the cost. Can you do this?

The answer is "Well, sort of". To get from the off-the-air tv to a computer monitor, you need a tuner, an if strip, an audio processor, a video detector, and a chroma demodulator.

You also may need a NTSC (Never The Same Color) composite video to RGB converter as well, if the monitor does not accept a composite video input. Sometimes a chroma detector chip can be modified to do this.

The circuitry that is needed, its design, and its alignment are far too complex to throw together on your own out of individual parts. You also would be reinventing the wheel.

Sadly, I know of no "plug and go" adaptor you can buy, but this is an obvious product that someday should appear at *Federated*, or at *Radio Shack* or wherever.

My personal solution to this was to go with the *Sony* KV1311-CR which is a combination receiver and monitor that actually is lots cheaper than many of the other RGB monitor-only products. But this particular receiver can't handle the higher horizontal scan frequencies involved with some Mac or IBM graphics modes.

For now, the best bet would seem to be to find a junked or otherwise trashed over VCR and lift the tuner and receiver electronics out of it. Or perhaps do the same thing to a conventional tv set that has problems with the picture tube or whatever.

Yeah, that is pretty much a wimpy answer. Let me know if you come up with a better one. This is also an ideal topic for some future *Radio-Electronics* construction project.

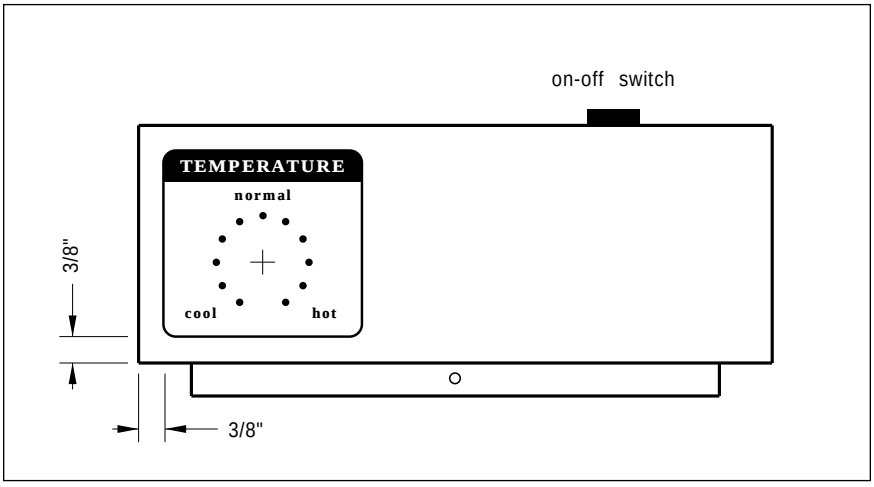


Fig. 5 – Position the decal exactly as shown here onto the front skirt of the right cover. A 13/32" hole is then drilled at the crosshairs.

Industrial Shopper Resources

As all of you long term Hardware Hacker readers have already found out, I am very big on trade journals. As we have seen in the past, those free electronic and all other trade magazines are outstanding resources that no serious hacker can afford to ignore, even for an instant.

This month, I'd like to make you aware of a sub-class of those trade journals that we just might call the *Industrial Shoppers*, and otherwise well known by their universal slang term of "the throwaways".

These are almost always oversize magazines published on slick newsprint and containing mostly zillions of ads and several bingo cards. Their editorial materials are primarily press releases and rehashes of all of their advertiser's product literature.

While almost a nuisance in any large electronics house, these throwaways are extremely valuable for you hackers and for any small scale operations in general.

Here's a sample list of a few of the many throwaways that have passed on through my *Synergetics* international corporate offices last week: *Pollution Equipment News*; *Electronic Components News*; *Plant Sites and Parks* (Great for free maps, but don't tell them I told you so), *Computer Products*; *Automatic ID News*; *Industrial Product Bulletin*; *Industrial Equipment News*; *Computer Reseller News*; *Product Design and Development*; *Instrumentation and Control News*; *Industrial Maintenance*; *American Laboratory*; and a final one that is known as *Electronic Buyers News*.

There are zillions more where all these came from.

As with all trade journals, you can get a complete list of the names and numbers from that *Uhlrichts Periodicals Dictionary* that you will find on the reference shelf at your local library. A phone call or a business letter will then get you a qualification card. Fill it out and away you go.

Or, to reveal a best kept insiders secret, you can obtain a free copy of most any magazine simply by requesting a sample copy along with an advertiser's rate card. Sometimes this even gets you a long term free subscription. But don't tell them who told you this.

The throwaways on such obscure topics as ranch management, jewelry, dentistry, forestry, on blacksmithing, pollution control, solar contracting, or heavy equipment maintenence can open up whole new worlds of ideas and products for you.

Check them all out. And don't ever leave any industrial plant without ripping off those qualification cards from all of the industrial magazines in their lobby.

New Tech Literature

The new *Murata-Erie* short form catalog has all sorts of unique hacker goodies in it, including the ceramic resonators, posistors, ultrasonic microphones, and humidity sensors. *NEC* has released a data sheet on their new *uPC1870CA* single chip television stereo MTV decoder.

National Semiconductor offers a new *Semiconductor Master Selection Guide*, while the new *Avantek Product Guide* has all sorts of info in it about microwave transistors and on their MMIC circuits.

There is a new *PAL* Device Data Book available from *Advanced Micro Devices*, along with a *Master Selection Guide* from *OKI Semiconductor*. Included are details on high quality speech chips. They even have their chips "live" on an 800 demo number.

A new *Linear Integrated Circuits Databook* from *Unitrode* has lots of ap notes and specialized circuits in it, aimed mostaly at switching mode power supplies. In particular, you might want to check out their UC3906 intelligent battery charger chip and its application note.

From *Data Translation*, a pair of I/O board catalogs. One is their *Image Processing Catalog*, while the other is their *Product Summary*.

There is also a high energy little shopper out known as *Nuts and Volts* that is crammed full of electronic and computer classified bargains. This beauty is chock full of outstanding hardware hacking buys This is very much in the "must have" category.

Turning to all my own products, if you are at all interested in active filters, check into my classic *Active Filter Cookbook*. As per usual, autographed copies are now available from *Synergetics*. Plus a reminder that my *PostScript Show and Tell* is now available to perform along with most any word processor on pretty near any personal computer.

And yes, we should shortly have full sets of the *Ask the Guru* reprints available. Write or call if you are at all interested.

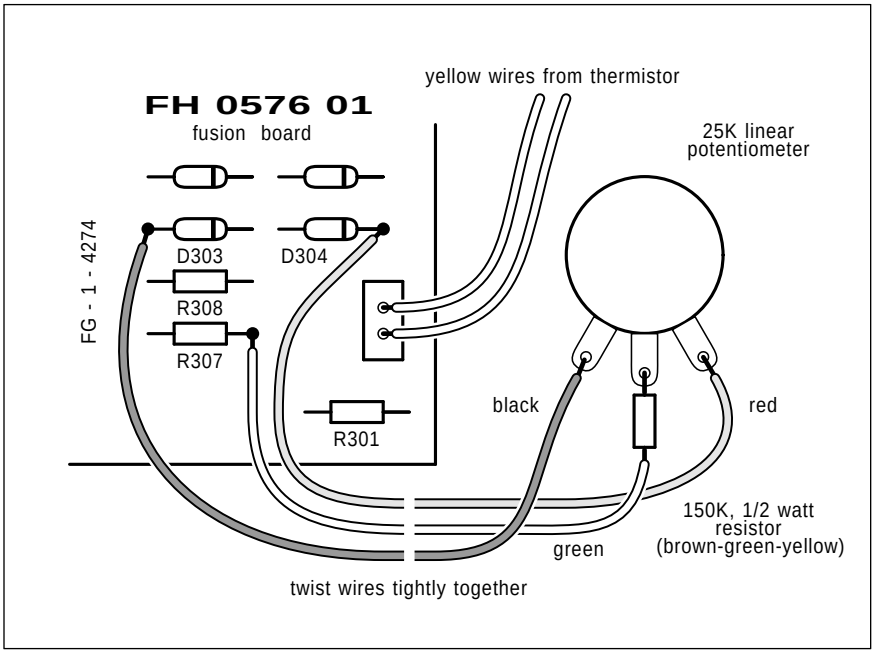


Fig. 6 – The pictorial diagram for the Canon fuser unit modification. The mod costs around 60 cents and can be done in twenty minutes.

Don Lancaster's

Hardware Hacker

December, 1988

Digital compass circuits
The Earth's magnetic field
Measuring magnetic fields
A low-end PostScript driver
Computer model prototypes

Do you recall the Santa Claus machine that we looked at a few columns back? Well, it turns out that you can now buy these off the shelf from the *3-D Systems* folks.

The price (a house and two cars) may seem a tad on the steep side at first glance, until you allow for the obvious "Uh 1 compared to what?" factor. And then it becomes a rather astounding bargain.

What this does is create a pastic prototype from a software data base through the selective laser hardening of a liquid plastic photopolymer. It is particularly good at machining the unmachinable, and can often do so in minutes rather than months.

There are quite a few new hacker opportunities here. One is to start up a prototype "service bureau", similar to the laser printer rentals at quick copy centers. Another is to come up with an ultra cheap and minimum Santa Claus system that can, in fact, get built on a hacker budget.

Meanwhile, bunches of you helpline callers have been asking for "low end" PostScript graphics and typesetting routines that will work on dot matrix printers. Well, to do this would be the equivalent of trying to install a new *Porsche* engine on a skateboard.

Nonetheless, *Lasergo* has freshly announced its brand new *GOscript* software that does give you several PostScript abilities for those cheaper and older printers. Cost is in the $200 range, and the software is primarily intended for IBM and its clones.

Our feature distraction this month involves a unique solid-state digital compass. But first, let's take a quick look at . . .

Computer Modeling

I must get a dozen calls a week from people that want to build some "simple" custom circuit that usually involves a keyboard, a display, some I/O, and perhaps some storage. What I will usually do is tell them that the product already exists, that it costs around $30, and that it is scunging away in their neighbor's driveway.

If you haven't guessed, it is called a *Commodore 64*, and thirty bucks is the typical yard sale price.

In this day and age, if you're designing *any* circuit that will involve more than four chips total, you will save an incredible amount of time, money, and frustration by modeling what it is that you think you want on a personal computer, doing as much as possible with the computer, and as little as possible with any external custom hardware.

Even if your ultimate goal is to build and sell a brand new product, starting off with a computer model will nearly always get you a better product out the door much faster.

Why bother with the model? First and foremost, software is far easier to change than hardware. Once you have something doing roughly what you thought you wanted it to, there will be many obvious improvements and changes that will just be crying to be made.

And the chances these days are overwhelming that a RAM-ROM-CPU approach will be cheaper, have fewer chips, and end up far more buildable than would a traditional circuit built up out of a handful of CMOS or TTL chips. Try it and see.

The Earth's Magnetic Field

There is a very obscure electronic study area known as *magnetohydrodynamics*. Basically, if you have a moving and a highly conductive pressurized gas or liquid, you can either generate an electrical current by applying a magnetic field, or else can apply an electrical current and in turn generate a magnetic field.

The liquid iron-nickel core of the earth does qualify as a humongous magnetohydrodynamic generator.

As such, it generates a very large, but rather weak, magnetic field. And that is why compasses point to the north. Well, sort of.

Actually, that north pole of the earth's electromagnetic field is only roughly at the real north pole, and it wanders around from time to time. It will even flop over and reverse itself completely every few tens of thousands of years.

The deviation from true north is called the *magnetic declination*.

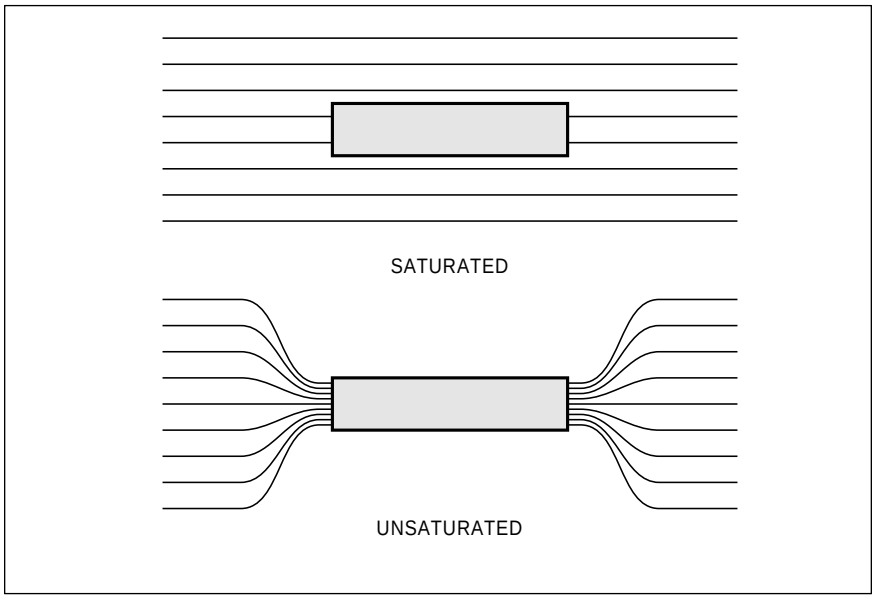


Fig. 1 – An unsaturated magnetic material will "pull in" the lines of force from the earth's or any other magnetic field. A saturated material will not.

Out here in Arizona, the magnetic declination is around 14 degrees easterly. In Kansas, the declination is nearly zero, while on the East Coast, the declination is a very few degrees towards the west.

You can locate the declination for your region from any USGS topographic map. To do this, you take the declination at the time the map was published and add the yearly drift rate to it, and multiply by the map's age. The drift rate will usually be negligible, except possibly for the oldest of maps.

It's obviously very important to know whether you are using "true" or "magnetic" north, or some serious errors will result. All your better grade compasses and survey instruments all have adjustment screws that let you preset your declination.

It is also very important to keep your compass completely and totally level at all times. The magnetic field is also three dimensional. It points "straight up" at the far north, "horizontal" near the equator, and "straight down" near the south pole.

That vertical component of the earth's field is called the *magnetic inclination*. One instrument to measure this is a *dipping needle*.

If your compass or whatever is not completely level, then your reading will end up as a mix of the horizontal and vertical field components, and will lie like a rug.

This gets nasty fast on an airplane that is not flying level. On a bank, you can get a severe *northerly turning error*. One cure here is to use a floating compass on a gyro that will stay level when the plane banks.

Why would you want to hack the earth's magnetic field? Orienteering, navigating, and surveying are the three biggest reasons.

Not getting lost is yet another.

By carefully measuring all the tiny variations over a accurately gridded area, it is sometimes possible to map buried features such as archaelogical sites, lava tubes, ore bodies, or even larger caves.

Further, there are two obscure but highly intriguing scientific fields that are called *archaeomagnetism* and *paleomagnetism*. These study the history of the field wandering, the first over thousands of years, and the second over hundreds of thous- ands. Accurate absolute dating is one of many unusual applications.

For instance, when a prehistoric fireplace is last used, its temperature exceeds the *Curie* point of the magnetic materials in its rocks, and all of the old fields are erased, just as you would bulk erase a casette tape.

As the fireplace cools, it takes an automatic snapshot of the inclination and declination at that instant and preserves it.

By carefully measuring this magnetic snapshot, the last use time of the fireplace can be accurately and absolutely dated. Even pots can be dated if you assume they were fired rightside up. And anything nearby can be relatively dated through guilt by association.

Simarily, the lava vents that cause sea floor spreading provide a unique locked-in history of all the magnetic reversals that took place over time. This lets you accurately date all the extruded lava and then measure the actual spread rate.

But, to hack any of this, we need some way of . . .

Measuring Magnetic Fields

The strength of the earth's field is roughly one *Gauss*. This is a rather weak field, and special tricks will be required if you want to measure it to acceptably accuracy.

Obviously, a compass works like a champ. My favorite here is the good old *Brunton*, which is really a cross between a high end compass and a low end survey instrument.

You can build your own compass by magnetizing a needle, sticking it through a cork and floating it in a cup of water. Ultra cheap compasses are available by the bagfull through *Edmund Scientific*.

Only there are problems. A compass will give you direction but not amplitude. It is also a mechanical device that's subject to both settling and vibration. Worst of all, it will have *damping* problems, as will any other moving mechanism.

The *Hall Effect* is one solid state method of measuring magnetic fields. This effect will cause a transverse voltage output to be generated in response to an input current in certain solid state materials. While Hall Effect devices are low in cost and readily available, most of them are nowhere near sensitive enough to use as a solid state compass.

The *F.W. Bell* people have some very large and very expensive Hall Effect devices that do seem to have enough sensitivity, but something better is clearly needed.

Another candidate is known as a *proton precession magnetometer*.

What you do is take a baby bottle full of water and then wind a zillion turns of wire around it. You apply a very strong current for a fraction of a second. This current aligns all of the deuterium atoms present in ordinary water into a fixed orientiation.

When the current is released, the

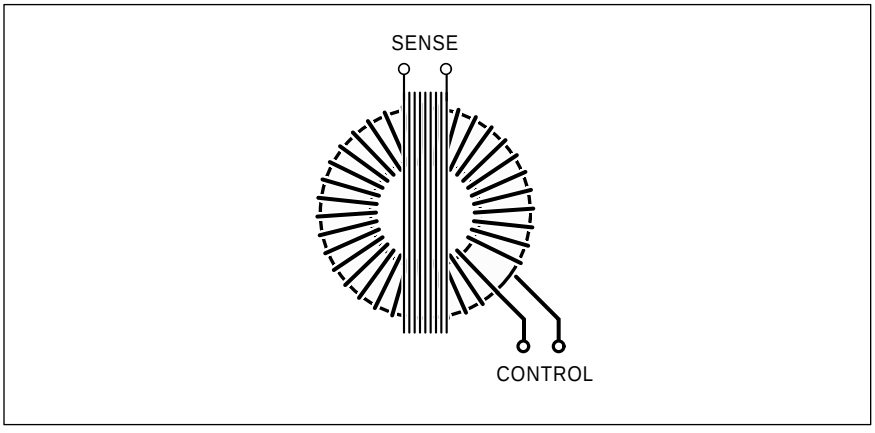


Fig. 2 – A fluxgate magnetometer is built by using a control winding that is able to alternately saturate and unsaturate its toroidal core. When the earth's magnetic field does get sucked into and out of the core, it will induce pulses into the sense winding. All these induced pulses are proportional to the strength and the direction of the field.

weaker earth's magnetic field will in turn cause these deuterium atoms to *precess* like miniature gyroscopes.

The precession in turn induces an audio signal of a microvolt or so into your winding. The frequency of this brief signal is then proportional to the strength of the earth's field.

One very big limitation to a proton precession magnetometer is that it only can measure the strength of the field, and not its direction. Another is that you are working with extremely small, quite noisy, and super brief output signals.

It certainly would be interesting to combine a modern digital signal processing chip with some better grade analog integrated circuits and see what sort of new precession magnetometer could result.

The most practical way of solid state sensing the earth's magnetic field is with a beastie known as a *flux gate magnetometer*.

Most magnetic materials posess what is called a B-H magnetization curve. Up to a certain level, they will behave linearly. Above a key point, they will *saturate* and lose all of their magnetic properties. What you have done is "filled" them with all of the magnetic energy that they can hold.

As figure one shows us, an ordinary magnetic material in its linear region will "pull in" magnetic lines of force, since the *permeability* of the material is greater than air.

Thus, a localalized distortion in the earth's magnetic field is created as the lines of force get "sucked in".

On the other hand, if you cause the magnetic material to saturate, there is no attraction or concentration of any additional field lines, and the earth's field will thus completely ignore the saturated material.

So, if you do switch, or *gate* any magnetic material into and out of its saturated state, you will alternately concentrate and ignore the earth's field. Should you now add a new *sense winding*, current pulses will be induced into that winding every time the earth's field enters or leaves.

The strength of the pulses will be proportional to the earth's magnetic field strength along the sensing axis.

The trick is to saturate and then unsaturate the fluxgate core without getting any of the drive current into the sense winding. Figure two shows us one possibility. A toroid of special magnetic material having a "square" B-H curve is used, along with a toroidal drive winding.

The sense winding is a linear overwrap of the toroid, that goes in one direction only.

With proper circuit design and a reasonable amount of luck, most of your drive current and its resultant saturating field will remain inside the toroid and thus not be picked up by the sense winding.

Figure three shows how a second *quadrature* sense winding can be added, giving us both a sine and a cosine output of the horizontal field component. We can now work with the *ratio* of these two signals and can often be more accurate.

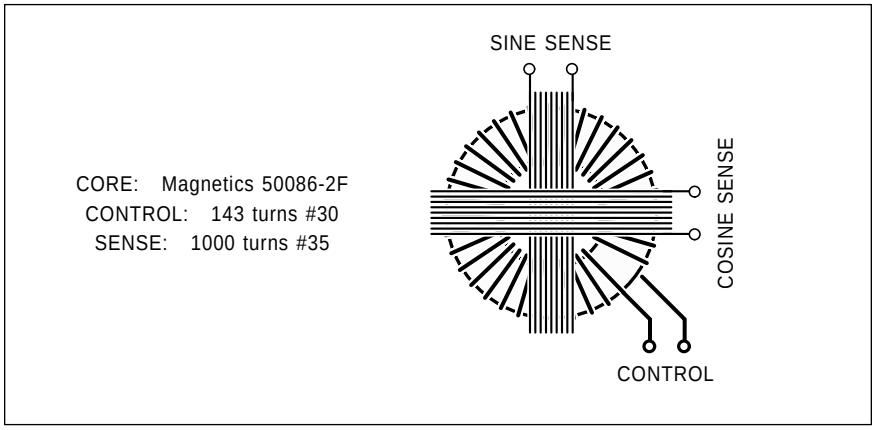


Fig. 3 – Adding a new quadrature sense winding will give you both the sine and cosine of the field strength. When one is weak, the other will be strong. The tangent of the final magnetic bearing is found by dividing the sine output by the cosine output. A list of possible winding details are also shown.

Solid State Compasses

A fluxgate magnetometer seems to be the best way today to building up your own solid state digital compass. Options include working direct or at the second harmonic of your drive frequency, or of using a single or a double quadrature sense winding, and of either working with nulls (by rotating the sensor) or else by using absolute amplitudes.

In aircraft or radio control model applications, a single fluxgate magnetometer can now replace *both* the traditional compass and its backup gyro. At the same time, a compensation winding can be added so as to minimize any northerly turning error problems or complications.

This new approach to navigation is ridiculously cheaper and far simpler. Figure four shows you some of the circuitry that is involved.

What you have here on the driver is a 60 kHz square wave generator that will drive both the magnetometer and a pair of output sensing gated half wave demodulators and amplifying integrators.

Those two quadrature dc output signals are proportional to the sine and the cosine of the amplitude of earth's magnetic field. They can be routed through an A/D converter and sent to a microprocessor for futher processing. Suprisingly, only a few hundred bytes of very simple code are needed to produce the complete digital compass.

One source for the prewound and ready-to-use flux gate cores are the *Precision Winding* people. Circuit boards and complete kits are now available from *Rusty Circuits*. And further info on licensing for resale or commercial use is available through *Doug Garner*.

For more construction details on building your own digital compass, see the NASA Tech Brief LAR-13560 on *An Improved Flux-Gate Magnetometer*, and *A Magnetic Heading Reference for that Electro/Fludic Autopilot*, as found in the December 1981 and January 1982 releases of *Sport Avaition*. Some updates to this earlier circuit design are once again available through Doug Garner. In particular, ask for the *Oshkosh 1987* and the *Sensors Expo 1987* reprints.

Solid state digital compasses are also newly becoming commercially available from various sources at fairly reasonable prices. Check out *Radio Shack* or else a local boating supply store for more details.

Those that I have looked at so far are British made and cost around $90. Unfortunately, they are not quite accurate enough for cave surveying and they lack a built-in level and inclinometer.

Two ready-to-use solid state and digital compasses are now available from *AutoHelm* and *KVH Industries*. Further info on these appears in issue ten of *Speleonics*.

The *Radio Shack* offering is an interesting car compass and a good hacker starting point, but it does not seem nearly accurate enough for my personal uses.

For this month's contest, just tell me something new and unusual that you would do with a new solid state compass, particularly if it measured amplitude as well as direction.

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

As per usual, send your entries directly to me and not to the *Radio-Electronics* editorial offices.

The Ultimate Mouse Surface

Some Tucson cave divers have put me onto a mouse working surface that is much better and much cheaper than just about anything else. It beats most of the other commercial products whiskers down.

So, run down to your friendly local neighborhood divers supply house or scuba shop and pick up a square foot or two of 1/8 inch nylon *wetsuit material*. The cost is around a dollar per square foot and it even comes in several decorator colors.

Round the corners and use it fuzzy side up.

New Tech Literature

Siliconix has some free samples available on their new ultra-fast DMOS transistors and analog gates. These dudes will switch in less than a nanosecond and can have on resistance values as low as 19 ohms. The obvious uses are in video switching applications and for various special effect generators.

Crystal Semiconductor now has an amazing new 16 bit A/D converter available that is priced in the $20 range. The part number is CS-5501. It is very easy to interface with most any personal computer.

The *Silicon Systems* people have a pair of new data books out, one on *Microperipheral Products*, and a second on *Telecommunications*. The products here include modems, call progress detectors, disk drive chips, and precision motor controllers.

The *Parts Express* people seem to be a good source for mechanical and electronic replacement parts for turntables, recorders, and VCRs.

Raytheon has a new data book out on linear integrated circuits.

For alternate energy materials and supplies, check out the *Real Goods Trading Company*. They are very big on twelve volt dc appliances and the lights for wind power systems. They are also a great resource for alternate lifestyle books and services.

Hewlett-Packard has a new and free guide out titled *Feeling Comfortable with Digitizing Oscilloscopes*. Unfortunately, H-P never has been, and probably never will be able to build a decent scope.

To do the job right, check into the 1989 *Textronix* catalog instead.

For information on alternates to traditional power generation that do include cogeneration, solar energy, energy management, conservation, and superconductivity, you just may want to check into the *Association of Energy Engineers*.

Turning to my own products, for lots of additional info on computer circuit modeling, you might like to try out my *Micro Cookbooks*, both volumes I and II. And, yes, we now finally have complete sets of edited and upgraded *Ask the Guru* reprints available, as well as lots of great stuff on the *PostScript* language.

As usual, your best calling times will be on weekdays, 8-5 *Mountain Standard Time*.

Let's hear from you.

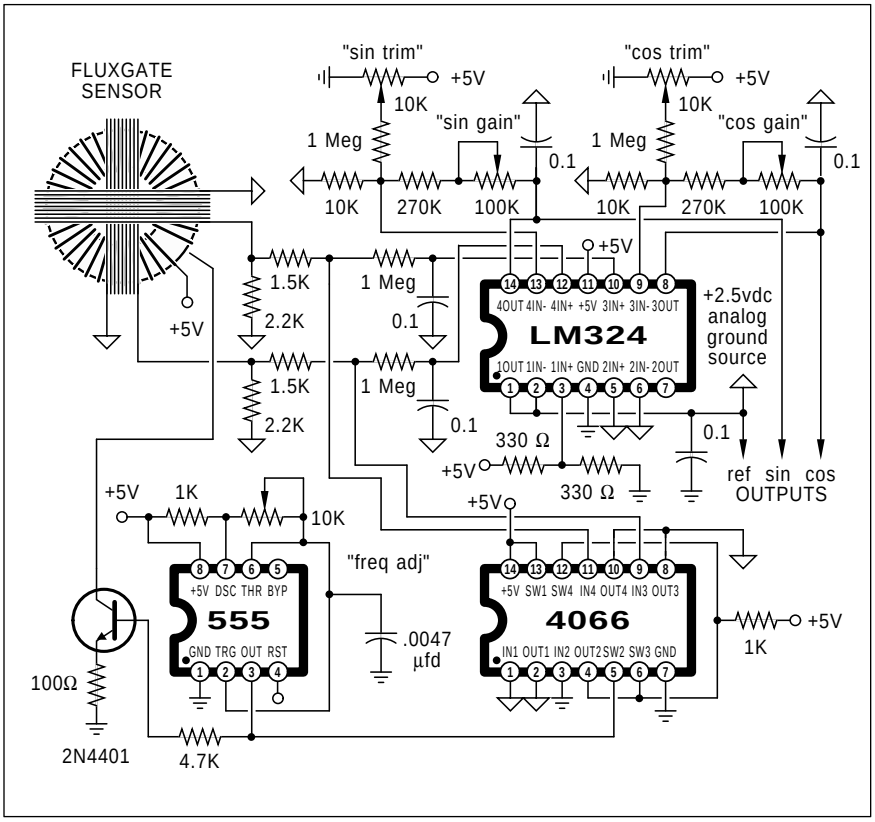


Fig. 4 – A simplified schematic of a solid state digital compass. The outputs are A/D converted and then routed to a microprocessor that handles the bearing calculations and a suitable digital display.

Don Lancaster's

Hardware Hacker

Surface mount parts kits
Visible and infrared filters
Digital sinewave generators
Innovative circuit suppliers
Getting and using data books

January, 1989

A reader recently criticized me against warning you so strongly about the anti-alias filtering in A/D converters. For most hackers most of the time, it is super important that you do understand the aliasing problem and then go far out of your way to absolutely *prevent* any high frequency aliasing from taking place.

But hail yaesss. Once you really understand all of the rules, you will sometimes want to selectively and creatively break them. That is what hacking is all about. Break the rules and you can sometimes leap tall buildings in a single bound. Just do not let the ground get in your way when you are done trying this.

For instance, you could build up a single conversion 60 kHz WWVB receiver by *purposely* aliasing. First peak sample your 60 kHz carrier input at a phase locked 60 kHz rate. And out comes a baseband digitally detected time code.

Starting with this column, all our *Names and Numbers* are now being twice verified. Once by an independent service bureau when my story is sent in, and once later by *Radio-Electronics* just before press time.

But there still are several of you who either insist on jamming the help line by ignoring the *Names and Numbers* entirely, or else end up calling all the names at random, rather than carefully reading the article to see who goes with whom.

As per usual, this is your column and you can get both tech help and off-the-wall networking by way of the phone number at the end of this volume. Best calling times are 8-5 weekdays, Mountain Standard Time.

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

Data Books

This time of year, there always seems to be a flood of brand new *data books* coming out. Data books are fat bound collections chock full of integrated circuit data sheets and application notes. They are second only in importance to those trade journals as a major resource for all serious hardware hackers. These are tools you simply cannot ignore. An extensive collecition of data books should be a major and a most important early hacking goal.

As a preliminary backing-up-for-a-good-start, you will want to get at least one hundred different data books. And you will want to keep all of them within three years of being current.

The price of a data book varies from free to optional to nominal. You pick these up by circling the bingo cards in such trade journals as *EDN*, *Electronic Design*, *Electronic Products*, *E.E. Times*, and such; or by writing or phoning the manufacturers and asking for a technical literature list; or by copping some older copies from an engineer or technician friend at most any electronics company.

While virtually all the integrated circuit manufacturers do issue data books, the really heavy publishers now do include *National*, *Motorola*, and *Texas Instruments*.

Any unbiased *Radio-Electronics* author would include *Intel* as one of those majors, but since my VW bus licence plate is 6502, I consider any integrated circuit whose part number starts with an "8" to be an intrinsically evil satanic tool.

Where to start? Certainly with National's *Linear Handbook*, with the Motorola *CMOS Data Book*, and Texas Instrument's multi-volumes of *TTL Data Books*. Then, one voltage regulator data book from any of the above. Unfortunately, it is hard to get free copies of these; just about everyone has to pay the going rate.

There's also a very useful series of limited information data books from *ECG* that cross the boundaries of the major manufacturers. These now do include their *Linear IC Manual*, the *Master Replacement Guide*, their *TTL Digital IC Manual*, their *Optoelectronic Manual*, and finally, their *Linear Module Manual*.

Beyond the majors, you'll have to dig deep to ferret out . . .

The Good Guys

Of the many hundreds of useful integrated circuit manufacturers and data book publishers, only a very few stand out as having really neat new goodies of major interest to hardware hackers. Who are they and where are they hiding?

A few years back, *Intersil* would have headed the list, with all of their outstanding clock, timer, voltmeter, stopwatch, and regulator chips.

Unfortunately, Intersil got bought out by GE, who got bought out by RCA who has recently put the whole works up for grabs in a yard sale.

It was almost as bad as when the *fourth* largest minicomputer builder merged with the *fifth* largest minicomputer manufacturer, and then very shortly went on to become the

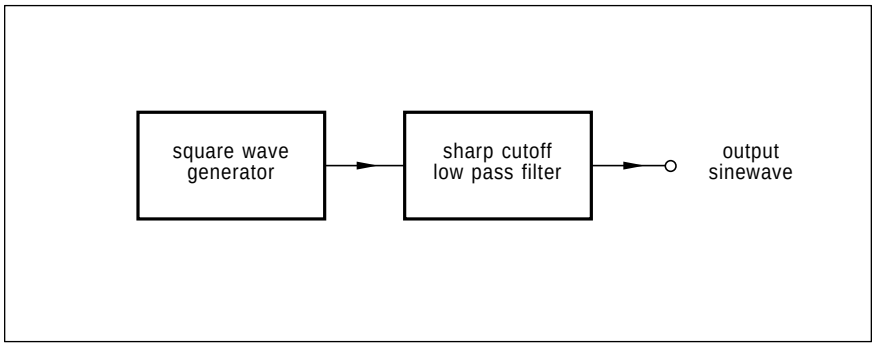


Fig. 1 – Brute force generation of a digital sinewave creates a square wave and then sharply low pass filters it. Triangular or certain "magic" waveforms can give you much better results than a square wave.

ninth largest minicomputer manufacturer. Oh well.

Do you want to know the *real* secret for the RCA-GE fiasco? It lies in their continued refusal to ever use any reader service numbers in any of their ads or product releases. For the want of a nail . . .

So, who can we put on today's list? Here's some possibilities:

Maxim Integrated Products has some absolutely outstanding voltage regulators, micropower CMOS circuits, A/D and D/A converters and power supply circuits. Fortunately, *Maxim* second sources many of the *Intersil* products.

Reticon is the obvious choice for solid state image sensors and video cameras, audio delay lines, and for new digital filters.

Dallas Semiconductor is heavy in clock chips and on sneaky ways to convert an ordinary CMOS memory into a non-volatile one. They also have some rather interesting shorter range receiver-transmitter security chips available.

We would have to include *SGS*, first for all their unique high power products, and secondly because they ended up with all the goodies that *Mostek* and *Thomson* used to make before *SGS* took them over.

For specialized communications chips that include tone encoding and decoding, scramblers, and the like, *MX-COM* also goes on the list.

And, stuffy as they seem, *Sprague* gets the nod for their power drivers, stepper motor control circuits, consumer ic's, and automotive chips.

Analog Devices gets included for all their various converter, multiplier, and amplifier products, along with their great and free *Analog Dialog* newsletter and fine ap notes.

To round out our list, for remote controls and satellite chips, *Plessey*; for opto stuff, *Siemens*; and for various RAM and EPROM stuff, *Hitachi*.

Let me know if you do have any other "good guys" favorites that I've missed, so we can pass them on.

Digital Sinewaves

There are plenty of advantages to generating sinewaves using digital techniques. One is that you can end up with extreme accuracy. A second is that you can rapidly change or sweep the frequency. A third is that multiple related channels are easily done, and a fourth is that you can often save quite a bit on expensive inductors and capacitors.

Pure sinewaves are often needed for electronic music, for very high quality synthesizers, and for radio frequency mixers. In any of these applications, any higher frequency harmonics can lead to all sorts of serious problems.

Let's look at four different ways to generate digital sinewaves. Figure one will show you the *brute force* method. Here you generate a digital squarewave and then low pass filter your square wave to extract the fundamental sinewave output. Some hassles here are that you'll need good filtering and that changing frequency over a very wide frequency range can get rather sticky.

One obvious improvement is to generate a waveform that has fewer or weaker lower frequency harmonics. A triangular wave can be a good choice. All of its low harmonics are weaker and can be easily filtered.

A much older trick is to route a triangular waveform of just the right amplitude through a pair of back-to-back diodes. At the right level, a high quality sinewave might result, without any filtering at all.

A second approach is known as the *phase lock loop* method, which does appear in figure two. Here you start off with a voltage controlled sinewave oscillator that often forms your ultimate output.

You then condition this output and divide it down by using a programmable counter and then phase detect it against your input reference frequency. The output of your phase comparator is filtered and fed back to the oscillator. If the frequency is low, the oscillator frequency gets raised, and vice versa.

Phase lock loops are handy when multiple channels are needed. For instance, to synthesize all of the AM broadcast frequencies, you would start with a 530 to 1650 kHz voltage controlled oscillator. This would get divided down by some programmable number from 53 to 165 and compared

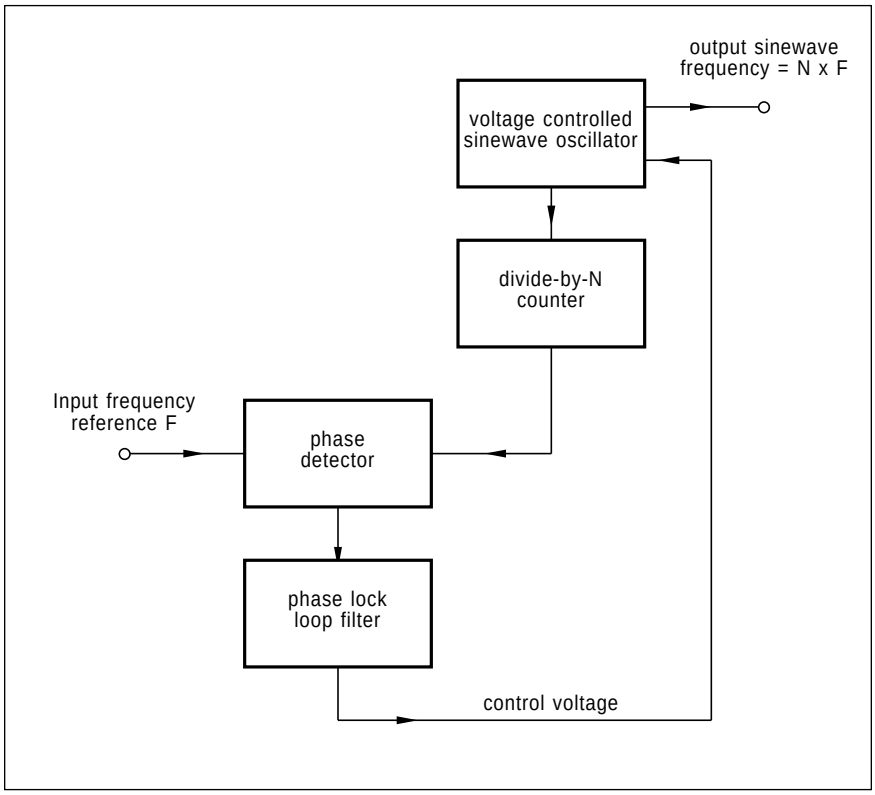


Fig. 2 – The phase lock loop can generate digital sinewaves and does get particularly useful where many different channels are desired for frequency synthesis. Changing "N" changes the channel selected.

against a 10 kHz precision reference. Such a device is called a *frequency synthesizer* and they are quite commonly used for radio, tv, ham, cb, and for other comm work.

Note that only one crystal or reference is needed, no matter how many channels are available.

Popular older hacker phase lock chips include the *Signetics* NE565 or the CMOS 4046. The "horses mouth" classic book on all this is *Phaselock Techniques* by Floyd Gardner.

Figure three shows us the *table lookup* method. Here you route a software or hardware counter into a lookup table that does compute the individual sine for each selected angle of the current count. This table lookup value is routed into an A/D converter and then gets output as a sinewave with fine steps in it.

Filtering is quite easy since all the harmonics of the steps are way above the fundamental. Often only a small capacitor is needed. Table lookup is ideal for sub-audio work such as that involved in brainwave research and seismology.

Table lookup is limited to lower frequencies, since your input clock is some 256 or more times higher than the output.

The Walking Ring Method

I have saved the most interesting method for last. All you really need to generate digital sinewaves is an unusual software or hardware counter and a few resistors. Figure four shows you an eight-step sinewave generator, while figure five shows you a sixteen-step version.

The walking ring counters, or the *Johnson* counters directly generate a squarewave of 1/N times the input frequency. This can be done in your choice of hardware or software.

For instance, here are the sequential states of a four stage walking ring counter that divides by eight ...

0000
1000
1100
1110
1111
0111
0011
0001

0000, etc . . .

At times, all three of the resistors are pulling up, while at other times, all three are pulling down. The output is a four step approximation to a sinewave. If you use an eight state walking ring counter, you divide by sixteen and can end up with an eight level sinewave.

What is really surprising is the harmonic performance. These are both carefully crafted magic waveforms. With perfect resistors, the first harmonics for your four stage generator are the *seventh* at 1/7th and the *ninth* at 1/9th the amplitude of the fundamental.

On your eight stage generator, your first harmonics are the *fifteenth* at a miniscule 1/15th and the *seventeenth* at 1/17th of the fundamental amplitude. Way down there.

Thus, these magic waveforms are extremely easy to filter, even over a wide frequency range. Often a single capacitor is all you need. Your counters might be built in either hardware or software. These are both good high frequency circuits since your clock only has to be 8 or 16 times that of the sinewave.

Two minor gotchas: Variations in resistor values and circuit strays can introduce a few other low ampli- tude harmonics into your output. And, with a hardware counter, you have to be extremely careful to eliminate any *disallowed states* by resetting to all zeros before you start. For instance, on the eight-bit counter, you are only using 16 of the possible 256 states; the other 240 can do all sorts of very wierd things if you inadvertently get into any of them.

One method of handling the disallowed states is to capacitor couple the feedback loop on the shift register and use a suitable pullup resistor. The all zeros state will automatically reset itself if you do this.

One place where you often will see walking ring sinewave generators is in all of the touch tone chips used in telecommunications. But this is a very general technique that has outstanding hacker potential.

More details on all this appear in my *CMOS Cookbook*, while all the hairy math behind it appeared in *Digital Generation of Low Frequency Sinewaves* by A. C. Davies, way back in the June 1969 *IEEE Transactions IM18, Number 2.*

For our contest this month, just dream up a new or unusual use for digitally generated sinewaves, or else a unique way of creating the actual digital sinewave generation. Paper designs are just fine. As per usual, there'll be twenty of my *Incredible Secret Money Machine* books for the better entries, and an all expense paid (FOB Thatcher, AZ) *tinaja quest* for the very best of all.

Send your entries directly to me, and not to the *Radio-Electronics* editorial offices.

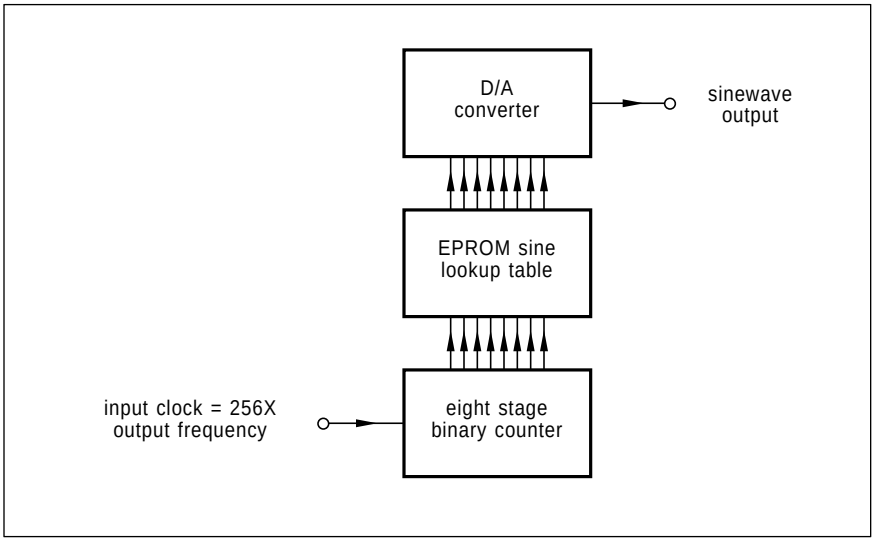


Fig. 3 – Table lookup of digital sinewaves gives a clean waveform and high accuracy, but is often limited to lower frequencies, especially when done by using personal computer software.

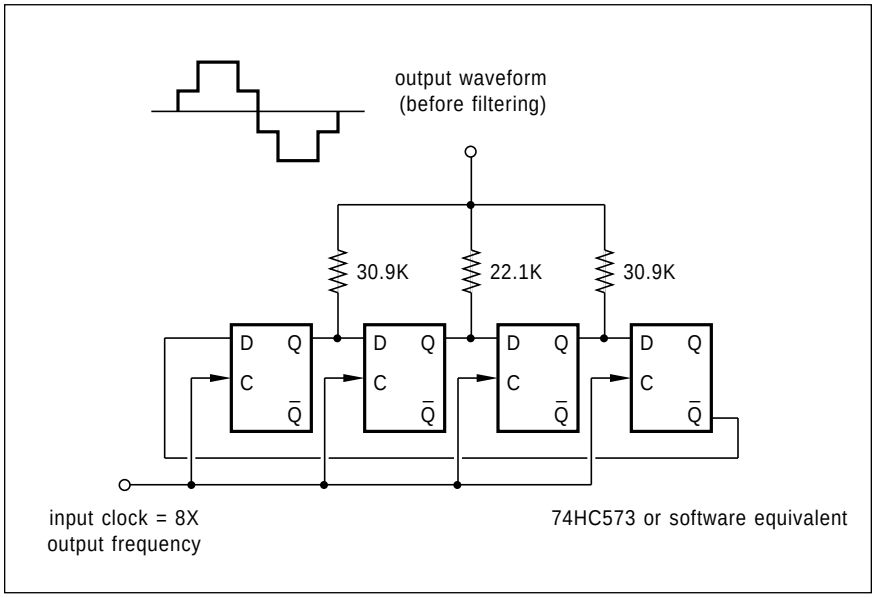


Fig. 4 – A Walking Ring digital sinewave generator of eight steps uses a "magic" waveform that has no low harmonics and thus is very easy to filter. The first harmonics are the seventh at one/seventh and the ninth at one/ninth of the fundamental amplitude.

Optical and Infrared Filters

If you are interested in improving the contrast of ordinary red, orange, or yellow LED displays, check out *Ulano* and ask them for some free samples of their *Rubylith* and *Amberlith* products. One sample book is enough for years of hacking.

Whenever you build an infrared remote control, it is very important to shield your receiver's photodector from all but the transmitted infrared control signals. Otherwise, sunlight or room illumination will swamp the input and either saturate you or else give you errors.

Several hackers have asked me just where you might go to get suitable infra-red filter material.

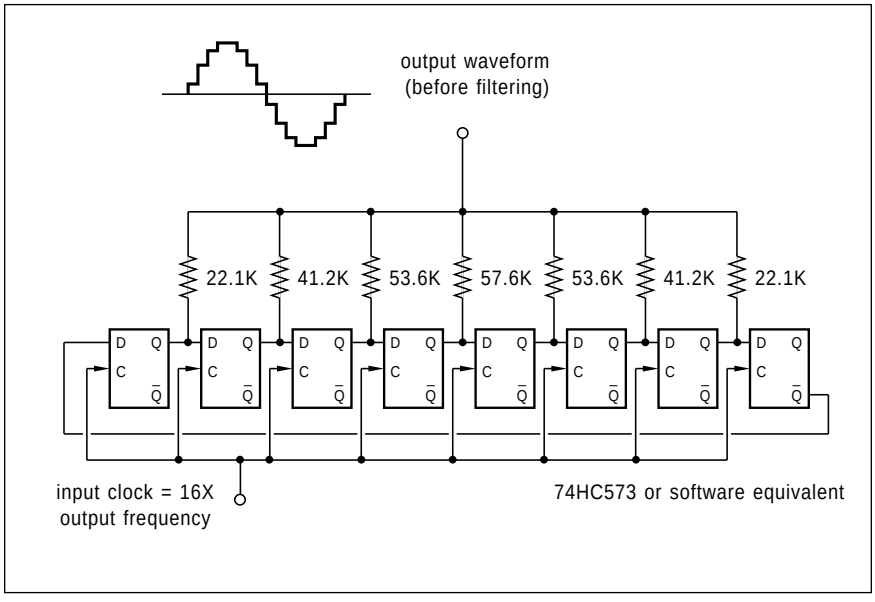


Fig. 5 – A sixteen step digital sinewave generator gives you an even better looking waveform. Here the fifteenth and seventeenth are the first harmonics present. That apparently "missing" resistor helps flatten out the waveshape.

Well, *Rohm and Haas* makes a special *#2711 Plexiglas* optimized for IR remote control filtering. The good news is that this costs around a nickel per square inch. The bad news is that these sell by the humongous sheet rather than by the square inch. One distributor is *Read Plastics*. Yes, they will cut.

For some real infrared filters at real infrared filter prices ($32 each), check out *Rolyn Optics*, in particular their model 65.1385. Another possible source for filter material is *Infrared Industries*.

New Tech Lit

Free sample strips of most of the common engineering thermoplastics are available from *Polypenco*. Low cost electroluminescent lamps in a variety of colors are now available through *Luminescent Systems*. A $50 evaluation kit of fourteen different stick-on thin film power heaters is available from the folks at *Minco*.

If you are into surface mounting at all, some low cost capacitor and resistor kits are now available from *Communications Specialists*. The resistors cost three cents each; the capacitors around thirteen.

Texas Instruments now has a data sheet on the new TLC32040 Analog Interface Circuit. This dude combines both a fast 14-bit A/D and a faster D/A converter on a single chip, along with all of the needed filters, sample-and-hold stuff, the works. Cost is around $30.

Steve Ciarcia's new *Circuit Cellar Ink* magazine is going great guns and is an absolute must for the serious hardware hacker. Meanwhile, Craig Anderton's new *Electronic Musician* magazine is now really taking off. Included are lots of hands-on MIDI construction projects. If you are into fancy optics, there's a trade journal by the name of *Lasers and Optronics* that you might want to qualify for.

Turning to my own products, the *Hardware Hacker Volume II* is now shipping and contains edited and updated reprints of all of my *Radio-Electronics* stuff so far, along with additional examples of PostScript goodies. Also available are my *Ask The Guru* reprints, volumes I and II from my sister column to this one over in *Computer Shopper*.

Don Lancaster's

Hardware Hacker

February, 1989

Pseudorandom sequences
High definition television
New white noise software
Electronic music resources
Top octave generator circuit

Many thanks for all of those calls and letters I got on those patents and patenting topics that we covered back in the October issue. Of those 415 responses to date, far and away the majority were in the "right on" or else the "If only I had known that six years ago" category, and I do thank you for them.

You'll be seeing other viewpoints on this from time to time over in the letters column. Since arguing one-on-one in the letters column is simply not my usual style I will repeat our key point here 1 For most of you hard- ware hackers most of the time, any involvement whatsoever with patents and patenting will almost certainly prove to be a monumental waste of time, energy, and money.

The overwheming evidence for all this is based on (A) my lifetime of experience directly involving inventions, patenting, creativity, design, and product development; (B) the independent and very thoroughly documented third-party studies of patent productivity; and above all, (C) the dozens of horror stories from current **Radio-Electronics** hardware hackers who have already gotten ground into hamburger by all of the absurdities that surround the patent process today.

I am sorry if I did offend one or two patent attornies and one or two others who do seem to be personally profiting from this very sorry state of affairs. I also extend my apologies to their BMW dealers.

Well, now that that we've got that hornet's nest kicked out of the way, let us take a swipe at another one. Which involves . . .

High Definition Television

The FCC recently mandated that all of the future high resolution video images done in this country will have to be NTSC (Never The Same Color) compatible. NTSC has been a thirty year old compromise which never has worked properly. It was long ago flushed by nearly all of the personal computer manufacturers.

Besides its being monumentally stupid, insanely protectionist, and incredibly hindsighted, this new ruling is precisely the same as asking a consortium of trolley car manufacturers to dictate a manditory new standard for the personal vehicular transport of the nineties.

Any disinterested outsider might conclude that a newer generation of fully digital and internationally standard "35 millimeter theater quality" interactive home video having eight multi-lingual stereo audio channels is an obvious product that should have a tremendous world-wide demand for the next several decades.

Where would the programming for true HDTV come from? Well (1) from local cable systems; (2) from newly upcoming generations of video tape rentals; (3) from videotape ownership; (4) from home video cameras; (5) from satellite reception; and at least in several other countries, (6) from direct broadcast satellites that go straight to the end user.

While only miniscule at present, I feel that a (7) interactive computer based Hypermedia should eventually become a most dominant source for HDTV programming. Once a HDTV standard exists, all of those major new personal computers suppliers are highly likely to adopt it, eliminating the artifical gulf between home video and home computing, along with that plethoria of less-than-HDTV monitor standards that exist today.

What about (8) network broadcast tv? At best, this would be a distant and eighth-rate source for the HDTV program material, and could be ignored entirely.

I personally feel that there has not been anything even worth watching on broadcast network tv for the last twenty years, and certainly nothing worth improving the definition of. To allow these people to enforce a lower quality and non-international poor patchwork "unstandard" done at the expense of the ultimate videophile is an unthinkable, inexcusable, and an outright atrocity.

As with streetcars, there comes a time when it is a good idea to tear up all of the tracks.

Further, virtually all of the HDTV reveivers will now include a microprocessor, a new frame grabber, great heaping bunches of additional RAM memory, and possibly even a digital signal processor.

Which means that real time video compression and/or decompression should be fairly cheap and simple to add to just about any transmission medium. Thus, we might easily end

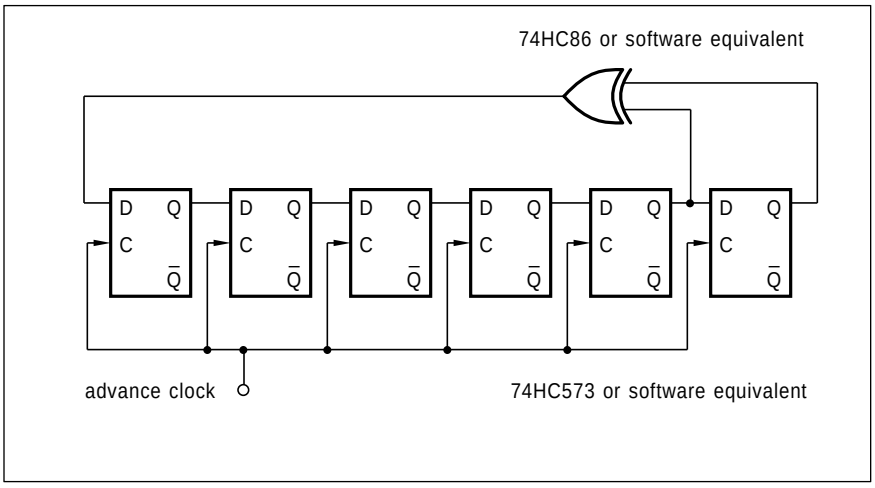


Fig. 1 – A six stage pseudorandom sequence generator gives you 63 six-bit binary numbers in an apparently random, yet exactly repeating order.

STAGES	LENGTH	FEEDBACK
2	3	1, 2
3	7	2, 3
4	15	3, 4
5	31	3, 5
6	63	5, 6
7	127	6, 7
8	255	4, 5, 6, 8
9	511	5, 9
10	1023	7, 10
11	2047	9, 11
12	4095	6, 8, 11, 12
13	8191	9, 11, 12, 13
14	16,383	4, 8, 13, 14
15	32,767	14, 15
16	65,535	4, 13, 15, 16
17	131,071	14, 17
18	262,143	11, 18
19	524,287	14, 17, 18, 19
20	1,048,575	17, 20
21	2,097,151	19, 21
22	4,194,303	21, 22
23	8,388,607	18, 23
24	16,777,215	17, 22, 23, 24
25	33,554,431	22, 25
26	67,108,863	20, 24, 25, 26
27	134,217,727	22, 25, 26, 27
28	268,435,455	25, 28
29	536,870,911	27, 29
30	1,073,741,823	7, 28, 29, 30
31	2,147,483,647	28, 31

Fig. 2 – Here are the "magic" feedback connections for many maximal length pseudorandom sequences. If two feedback numbers are shown, you EOR them together. If four numbers are shown, you EOR by pairs and then EOR the two intermediate results. Either hardware or software may be used.

up with newer HDTV transmission bandwidths which are ridiculously *lower* than NTSC standards.

Most newer HDTV displays will probably be able to accept older PAL, NTSC, RGB, or SECAM programming inputs, and even spruce them up a tad before they display them. The key question is whether an older NTSC television set that inadvertently got plugged into some HDTV program source has got to be able to display something viewable. That present ruling makes about as much sense as requiring that all CD ROM disks be able to output low fidelty audio when played with a cactus needle on a 78 RPM wind-up turntable.

As per usual, I do welcome your comments on this. In fact, let's have us another contest. Write me with your thoughts on HDTV. There will be all the usual *Incredible Secret Money Machine* books for the best dozen or two entries, with an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two for the best entry of all. Naturally, you do not have to agree with me, but the more thought out and the more coherent your response, the better will be your odds of winning anything.

Do send your entries directly to me per the *Need Help?* box, rather than to the **Radio-Electronics** editorial offices. No fair sending all the "right on" responses to me and all the "up yours" ones to the letters column.

Pseudo-Random Sequences

I've long been fascinated with both random and pseudorandom numbers and their generation.

Truely random numbers are quite difficult to generate, and it is very easy to introduce all sorts of subtle bias into them. One fact that many hardware hackers refuse to accept is that virtually any and all attempts at making something more random will nearly always have the exact opposite of the intended effect.

A *pseudorandom* sequence is some long string of numbers that is able to exactly repeat itself, but any shorter portion of which appears totally random, and apparently obey all the rules of random numbers and their distributions. This concept of "noise that repeats" is especially handy for industrial testing, for military radars, for security systems, and for such things as a redeal of the same card hand in a game or simulation.

To generate a new pseudorandom sequence, you can use, of all things, a *pseudorandom sequence generator*. Golly gee, Mr. Science.

To do this, you take a plain old hardware or software shift register. You then choose several outputs and exclusive-OR them all together and use the resulting one or zero as an input for the next clocking cycle.

One of two things is now likely to happen. If you do pick the wrong feedback combinations, then the shift register will shortly hang in its all ones or all zeros state. But with just the right feedback combination, the shift register will become some sort of a counter of some length, that goes through a series of count values in a repeating and predictable order.

The trick is to pick out the longest possible sequence length for any shift register by finding exactly the right "magic" feedback combinations.

This is known as a *maximal length sequence* and is always *one less than* the total possible number of states in the register. Any shorter groupings within one of these maximal length sequences will appear to be random and will obey most of the properties of real random numbers.

Figure one shows you a six stage pseudorandom generator that is able to generate a sequence that is 63

counts long. You might like to list all of the states to prove to yourself that short samples really do seem random, although this whole sequence does repeat once each 63 clocks. I used this way back in my *Psyctone* project eons ago in the "golden age" of good old *Popular Electronics*.

You can create up to four related maximal length sequences, a "forward" one and its complement, and a "backward" one and its complement. There is one big gotcha: you must never start with the "all zeros" state or your generator will hang, permanently outputting zeros.

For many uses, you'll want to use much longer sequences. Figure two lists the magic feedback combinations needed for the various maximal length sequences. A very few of the longer ones are not "quite" maximal, but they are the best that anyone has ever found so far.

A very interesting pseudorandom generator for computer use appears in figure three. This is a 31 stage shift register, which gives you a sequence length of 2,147,483,687 before it repeats. Yet, it is able to deliver an apparently random one or zero in 40 microseconds or less with most popular personal computers.

The all time whiz bang expert on random or pseudorandom anything is Donald Knuth in all his *Art of Computer Programming* volumes. These are available at any large technical library. I have also gotten into this rather extensively in my *Apple Assembly Cookbook* where you might find several ways around the many fatal flaws in the Applesloth random number generator, along with lots of useful ways to generate and test random and pseudorandom numbers of nearly any size.

A White Noise Source

As a quick and dirty example of a 31 stage pseudo-random generator, figure four shows you a short machine language routine that makes an Apple IIc, IIe, or IIgs sound like it is frying itself in its own grease. I will leave it up to you to dream up some of the more fiendish applications for this short code module.

On every binary one, the speaker cone gets whapped, while it stays where it is on a zero. As shown, the code is very slightly pinkish, rather than a pure white noise. I'll let you add those few extra bytes needed to equalize the timing so that each loop takes exactly the same time, regardless of when the cone gets moved.

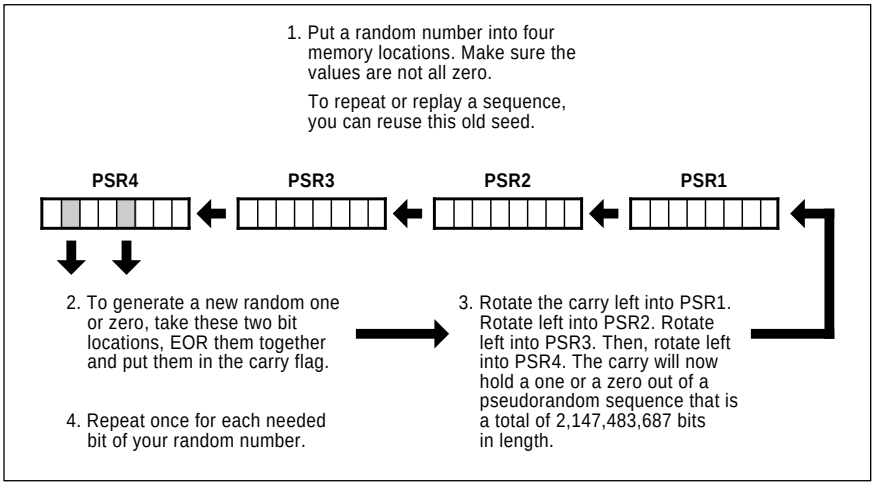


Fig. 3 – A 31 stage pseudorandom sequence generator done in software will produce a "random" string of 2,147,483,687 ones or zeros before it will start to exactly repeat. Typical execution time is under 40 microseconds.

You can use similar code to explore other pseudo-random lengths. As the lengths get shorter, you will first note some structure. For even shorter lengths, actual tonal color will result. Try it and see.

And here's something not quite related you might like to play with: If you take any old 30 bit digital word and whop the speaker on the ones and not whop it on all of the zeros, different *timbre*, or tonal values will result depending on the strengths of the harmonics you are listening to.

For instance, getting a very strong fundamental and no low harmonics should result in a flute-like sine-wave, while any waveform having a strong third, fourth, and fifth, but a weak first and second should give a major chord, *even though you are only pushing a speaker cone all the way in or all the way out.*

Thus, you can easily generate pure sine tones, as well as two or three apparent notes at once by using this simple technique.

Now, it is easy to pick words at random and listen to the results, but how do you *purposely* design your selected word for the desirable harmonic structure? This is a very sticky math synthesis problem.

Fourier series anyone?

(1) On an Apple II+, IIc, IIe, or IIgs, get into **BASIC.SYSTEM** and do a **CALL -151** to get into the monitor.

(2) Then, enter the following code:

```
0300:  4C 07 03 27 0C A1 C9 AD  <cr>
0308:  06 03 0A 0A 0A 4D 06 03  <cr>
0310:  0A 0A 90 03 2C 30 C0 2E  <cr>
0318:  03 03 2E 04 03 2E 05 03  <cr>
0320:  2E 06 03 4C 07 03 11 11  <cr>
```

(3) Finally, do a **BSAVE KFC.VIRUS, A$0300, L$28, D2**

(4) To test, use, or abuse your code, do a **BRUN KFC.VIRUS**

Fig. 4 – This white noise generator makes an Apple computer sound like it is frying itself in its own grease. A 31-stage pseudorandom generator is used. Except for stress-induced medical effects on the system owner, the code is more or less harmless.

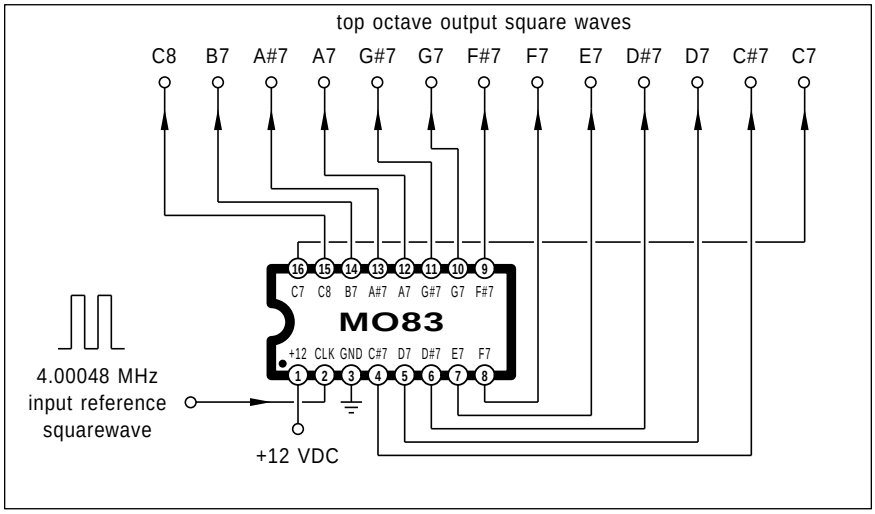


Fig. 5 – A top octave generator integrated circuit takes an input reference square wave and divides it down to approximate the thirteen uppermost notes on an electronic organ. Further binary division of each output can generate all the needed lower notes. This SGS part replaces the Mostek MK5083.

Can More Than One Monitor be Used With a Personal Computer?

Sure, if you are careful enough about it. With some luck, you might even be able to put some of the monitors as much as several hundred feet away from the computer.

There are some gotchas involved, though. First, it is far and away best to run one continuous cable from monitor to monitor, rather than using a bunch of separate cables from the computer to each monitor.

Second, just about all the monitors have provisions to terminate or not terminate their inputs. Termination is done by putting a 75 ohm resistor directly across the video input. Some times this is done with a switch at the back of the monitor. At other times, you have to use a solder jumper, or else a custom plug of some sort.

Regardless of the method used, *only the final monitor in the daisy chain should be terminated!*. All of the intermediate monitors should be switched to their unterminated, or high input impedance, settings.

Naturally, you should keep your cables as short as possible, and never use a long cable without its far end terminated. For longer runs, you will get the best results by using "real" coaxial cable and BNC connectors, instead of plain old audio cable and the usual RCA plugs.

For extremely long cable lengths, you might need a video buffer of some sort. RCA has a 3450 video op amp that could be useful here. There is also a new product called the *Rabbit*, that's in the *Heath* catalog, among many other places. This gives you a way to extend VCR signals all over your house by cable. I am not sure if this product can also handle baseband video.

Top Octave Generators And Keyers

If you wanted to design your own home, theater, or a church organ from the ground up today, far and away the simplest and the cheapest way to obtain the highest possible quality results would be to model what you are after on the *Ensoniq* synthesizer inside an *Apple IIgs* and later on tack on a MIDI card or two.

Nonetheless, I do get an amazing number of calls from all you **Radio-Electronics** readers who want to do things the "old way", using those rather obsolete and horribly limiting top octave generators and keyers.

I suspect this is mostly the "Gee dad, its a Wurlitzer" folks trying to distance themselves from all those "Heavy Metal" punk rockers. Like it or not, all those punk rockers have dumped many millions of dollars and hundreds of thousands of manhours into developing very simple, ultra cheap, and highly effective all-digital synthesizers that can now easily duplicate any known or any imagined musical instrument, and do so with stunning accuracy and clarity.

Well, if it is top octave generators you want, then top octave generators you'll get. Figure five shows you how one single input reference square wave and a top octave generator can generate thirteen of the highest needed keyboard notes. A second *keyer* chip can then divide these notes down and turn them on and off in an organ-like manner.

Roy DeVault of *Devtronix* has lots of top octave generators and keyer chips and boards available, and is more than glad to sell them to you at low cost in very small quantities. Roy provides everything from single chips up through new and used complete organs, besides being one incredible information source. He welcomes your calls.

If you do decide to build a top octave generator for use as a pitch reference or a tuning instrument, be sure to note these two big gotchas: Your output tones absolutely *must* be filtered to produce the ultra-pure sinewaves for tuning purposes. And, you have to be able to vary your pitch by as much as 30 percent when tuning any piano. Because of the enharmonic lateral stiffness of piano strings, a piano keyboard has to be "stretched", rather than tuned to the textbook frequencies. Otherwise it will sound awful.

The stretching is as much as one third of a semitone for the lowest notes, and around half that for the highest. Watch this detail.

Resources for Electronic Music

As with any field, the bookstores, tech journals, and popular magazines that service electronic music interests are your obvious starting place. It also helps if you can carry a tune in a bucket.

The *Electronic Music Resources* list of figure six gives you some of the more important and more interesting places to go to get started.

Probably the best collection of the electronic music, synthesizer, MIDI, audio and video production books in the world is available through the *Mix Bookstore*. Their free catalog is

ELECTRONIC MUSIC RESOURCES

Audio Amateur
Box 576
Peterborough, NH 03458
(603) 924-9464

Devtronix Organs
6101 Warehouse Way
Sacramento, CA 95826
(916) 381-6203

Electronic Musician
19725 Sherman Way, Ste 160
Canoga Park, CA 91306
(818) 709-4662

Keyboard
20085 Stevens Creek Blvd
Cupertino, CA 95014
(408) 446-1105

Journal AES
60 East 42nd Street, Rm 2520
New York City, NY 10165
(212) 661-2355

Journal ASA
335 East 45th Street
New York City, NY 10017
(212) 661-9404

Mix Bookshelf
6400 Hollis Street #12
Emeryville, CA 94608
(415) 653-3307

Music, Computers & Software
190 East Main Street
Huntington, NY 11743
(516) 673-3243

Music Technology
22024 Lassen Street, Ste 118
Chatsworth, CA 91311
(818) 407-0744

Musician
1515 Broadway
New York, NY 11743
(212) 764-7300

Rolling Stone
8500 Wilshire Blvd, Ste 926
Beverly Hills, CA 90211
(213) 659-1242

Speaker Builder
Box 494
Peterborough, NH 03458
(603) 924-9464

Fig 6 – Here's a starter list of several of the more important electronic music magazines and related resources.

an absolute must that you will definitely want to check out.

Of all the publications that are listed though, I think the *Journal of the Audio Engineering Society* has the best long term track record on both the tech fundamentals and on all those roots of the digital synthesis revolution, while Craig Anderton's *Electronic Musician* offers "hands on" coverage of the very latest and the very best.

Craig also does have a number of outstanding books in print. His *MIDI For Musicians* is a real classic, as is his older *Electronic Projects for Musicians*. Mix carries both of these.

Let me know if there is anything else that you think should be added. So far, we have done some resource collections on handicapped aids and electronic music. Printer resources will appear next month. Which others do you want?

New Tech Lit

Free samples of several low cost connectors for pneumatic robotics are available from *Ark-Plas Products*. One good and cheap source for custom photochemical etching of thin materials is *Fotocut*. Many thanks to *Model Railroader* magazine for this hard-to-find item. Besides absolutely outstanding tech writing, you might want to check out this mag for very unusual tools, ideas, and materials.

By the way, if you ever do run into a model railroader, just tell him you are now scratch building an 0-2-0 articulated Camelsback, and watch his eyes light up.

International Rectifier now has a free *Microelectronic Relay Designer Manual*, mostly on their *ChipSwitch* solid state interfaces. These are real convenient for light dimmers, disco chasers, color organs, and the like. We will see more on this next month.

Allied Electronics has a new free *#889* Catalog. Allied is one of the oldest of those "old line" electronics distributors and are at long last back to offering lots of products stocked in depth at tolerable prices.

The free *Hewlett-Packard Journal* is certainly worth a subscription to. The October 1988 issue has good stuff in it on the SCSI interface funda- mentals and on some cheap optical encoders. On the other hand, I simply cannot even conceive of anyone ever actually buying one of those diskless workstations they're highly touting in the same issue.

Even when spelled correctly, I do feel that diskless workstations are both fascist and on the stupid side of dumb. Its much simpler to take the epsilon minus who suggested buying diskless workstations and then either forcing him into early retirement or staking him to an anthill.

One good and low cost source of miniature low frequency crystals is *Statek*, who have a number of data sheets, price lists, and ap-notes on hand. Ask for their literature list.

At one time, all the low frequency crystals were very bulky, unreliable, and quite expensive. *Statek* has now completely turned this around, with very low prices, very small sizes, and good reliability, even when using the micropower oscillators and filters.

Two sources of low cost infrared "people detectors" using new pyroelectric sensors include *Amperex* and *Pace*. They both have several very detailed application notes and data sheets available.

One of the sneakier use tricks is to use Fresnel lenses with "hot" and "cold" imaging areas. As someone walks by, they will automatically "chop" themselves into an ac signal at their peak sensitivity of these pyroelectric motion detectors.

Turning to my own products, yes, we now have a complete bound set of reprints to all of the *Hardware Hacker* columns that you've seen here to date, along with volumes I and II of my sister *Ask the Guru* column that you'll find in *Computer Shopper*. And, of course, my classic *TTL Cookbook* and *CMOS Cookbook* remain available to those of you wanting to pick up the basics of digital integrated circuits.

As always, this is your column and you can get tech help and some off-the-wall networking per the end box. You'll find the *Names and Numbers* list combined with all the others in the ending appendix. Let's hear from you.

Don Lancaster's

Hardware Hacker

March, 1989

A new "disco" circuit
Zero crossing detection
AC power load interface
Phase controlled dimming
Dialog information services

Several helpline callers have now asked me what the main differences are between that BSEET supertech degree and the BSEE engineering degrees. One quick answer is "around a million dollars or so".

That is roughly how much extra lifetime income the BSEE degree will garner on the average, including the benefits, perks, retirement plans, any investments, the other amenities, and also allowing for inflation.

It is no secret that the technicians and supertechs will often do all the work and the engineers get all of the credit, all of the pay, and all of the promotions. Not to mention both an office and a real desk.

Many of the larger and "old line" electronics outfits tend to treat their techs and supertechs as second class citizens, severely limiting all of their advancement and salary opportunities. These problems are especially acute in aerospace and defense.

So, *if* you can handle all the needed math and can pass all the required non-engineering courses, then the BSEE will offer something around a 26.5 decibel better cost/ benefit ratio over the BSEET degree.

The helpline response over the fluxgate magnetometer compass we looked at back in the December RE has been utterly astounding, and I do thank you. Another source for the fluxgate magnetometer compass kits is *Rusty Circuits*.

Radio Shack also now has a low cost solid state fluxgate automotive compass. This does appear to be a two-piece unit that has the fluxgate sensor windshield mounted by way of a short length of five conductor cable. The display itself is a servo-like pair of coils that can activate a magnetized compass rose disk. The accuracy does seem very limited, but it costs only $49.95. This should hack beautifully. More on this whenever.

Radio Shack also has a new and "intelligent" power strip that turns on all of your computer peripherals or home video accessories whenever a main load is switched on or off. A few helpline callers have been asking for circuits to do this.

Several of you Canadian readers have been wondering why very few of those smaller electronics outfits will even give them the time of day. The response is that there are more than enough hassles involved that it is almost always a net loss of energy and time and money to do so.

My personal horror stories here include your Canadian post office refusing to accept my first class mail, and waiting three hours in a bank for them to decide to use the Canadian exchange rate for any bank in Nova Scotia. Honest. They couldn't find any country that was named Nova Scotia, so they had to call up the head office four times in a row. These epsilon minuses were about as sharp as five pounds of raw liver.

Finally, they ended up giving me $7.65 for a $24.50 check. Life is too short for this sort of thing.

Our focus this month is on the electronic lighting controls for rock concerts, discos, theater lighting, for color organs, and whatever. But first, let's get up to date on . . .

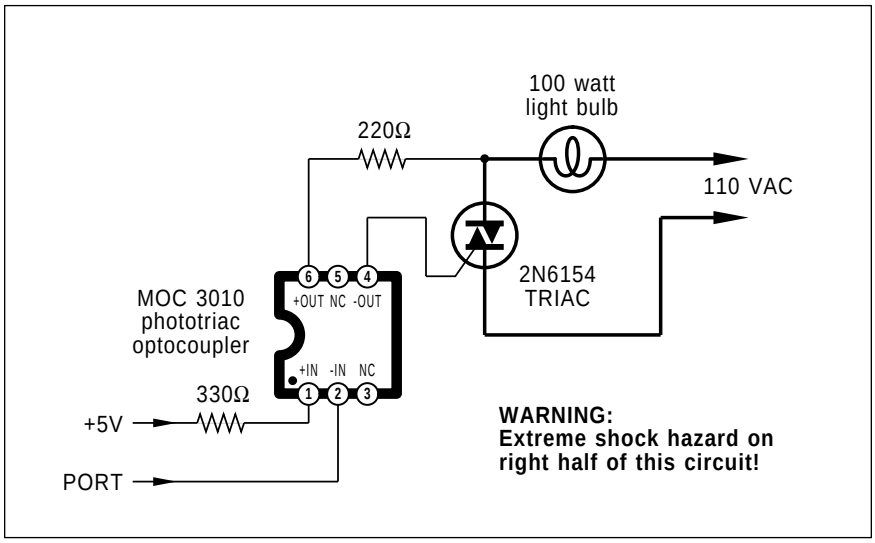


Fig. 1 – This ac power output interface lets you directly control 100 watt lamps and other high power loads from your microcontroller or your personal computer. The special phototriac optocoupler provides safety isolation. Note that a low logic input will light the lamp.

Library Research

Several exciting things have been happening at the library lately. First and foremost, lots of libraries are now putting their card catalogs and public serials lists onto new on-line electronic BBS bulletin boards. So, you can now find out what's available without leaving home.

One example of this would be the *Arizona State University* library BBS reachable at (602) 965-7003.

The second really big news item for all of you hackers is that many libraries are now offering the great *Dialog Information Service*. Dialog is a new "supergroup" electronic search service covering many hundreds of electronic data bases. If the topic that you are reserching is even remotely popular or scholarly, you will definitely find it on Dialog.

While those $2 per minute typical *Dialog* charges would seem a tad on the steep side at first glance, (A) this is ridiculously and insanely cheaper than getting the information by any other means; (B) the searches are far more thorough and more complete than you could possibly hope to do

by yourself; and (C) with practice and help from the trained librarian, you can make all your searches extremely time efficient.

As an example of one tiny nook over in one obscure *Dialog* corner, there is the *INSPEC* data base. This holds four million abstracts of just about everything that has been done recently in the fields of physics, in electronics, and in computer science. INSPEC will often be a hacker's first and last stop.

Usually, you will use *Dialog* to get the abstracts of the key papers of whatever it is you are seeking. From there, you can go to the *Engineering Societies Library* or else *UMI* for the full text reprints.

UMI is the usual place a hacker or researcher would normally go to get low cost reprints on most *any* topic, so long as you do know the *exact* publication title and all of the page numbers you are after.

Naturally, there's also the good old *Interlibrary loan* service that most libraries provide, as well as digging out the papers by yourself.

Yes, you can subscribe to *Dialog* on your own for a fairly reasonable annual fee. Sadly, the hidden costs of all of the needed manuals and all the time needed to learn them and keep them current will eat you alive. Use the library instead.

As a quick reminder of some of the other obscure interesting stuff in a good library, there is that *Thomas Registry of Manufacturers* which lists nearly everyone who makes or resells anything anywhere, and *Uhlrichts Periodicals Dictionary*, which shows you who publishes all those many tens of thousands of magazines, the scholarly publications and the trade journals that are available (many are free to "qualified" subscribers), along with the *Science Citations Index*, which, miraculously, often can let you search *forward* through time, picking up *newer* references.

Additional details on much of this do appear in my *Incredible Secret Money Machine* book.

AC Lighting Controls

There's lots of interest these days in controlling large 110 volt ac light bulbs directly through your personal computer. The important uses include psychedelic lighting shows, advertising signs, rock concerts, theater and disco lighting, laseriums, "new age" relaxation techniques, casinos, traffic displays, scoreboards, those store window displays, etc. etc.

I guess I kinda pioneered at least part of this field. Way back then, we were interested in *color organs*, or circuits that converted music into home audio lighting displays. For an ancient history course, do check my *Solid State Color Organ* back in the March 1963 *Electronics World*, or the *Colorgan* project that you will find way on back in the February 1965 issue of **Radio Electronics**.

Or perhaps the good old *Musette* (July 66) and that *Psychedelia I* (Sept 69) that also appeared later on in *Popular Electronics*.

At any rate, what I would like to do here is review the fundamentals of modern and personal computer based solid state ac power control.

Obviously, you cannot just hang a 100 watt light bulb onto a computer output port. The digital logic signal must first become safety isolated to eliminate a serious shock hazard and then somehow get "amplified" up big enough to control the lamp.

Figure one shows you a typical computer power interface circuit. The two key parts are a very special form of optocoupler known as a *phototriac isolator*, and an ac power controlling switch called a *triac*.

The triac is basically an efficient bilateral latching ac power switch. Applying a small amount of current in either direction into its *gate* terminal turns on an electronic switch between the main T1 and T2 terminals. The switch then stays on until the load current drops to zero during the next ac half cycle.

The phototriac isolator consists of a light emitting diode that shines on a miniature and lower power light sensitive triac. Whenever you apply an input current to the optocoupler, the internal LED will light and shine on the little internal phototriac, which can then turn on and reach out and turn on the main power triac.

You get safety isolation because there is nothing but a beam of light between your input and output. Once again, you will find several different types of the optocouplers. It is most important to use a phototriac style that can withstand at least a 200 volt ac output waveform.

Note that this circuit is shown to you slightly differently than would be intuitively obvious. Most TTL and NMOS computer port lines are much better at sinking current to ground than they are at sourcing it, so it makes sense to allow a *low* output logic level *light* both the optoisolator and the power lamp loads.

Thus, for the most reliable circuit, you connect the *positive* terminal of the optoisolator to +5 volts by way of a current limiting resistor, and the *negative* terminal to your computer

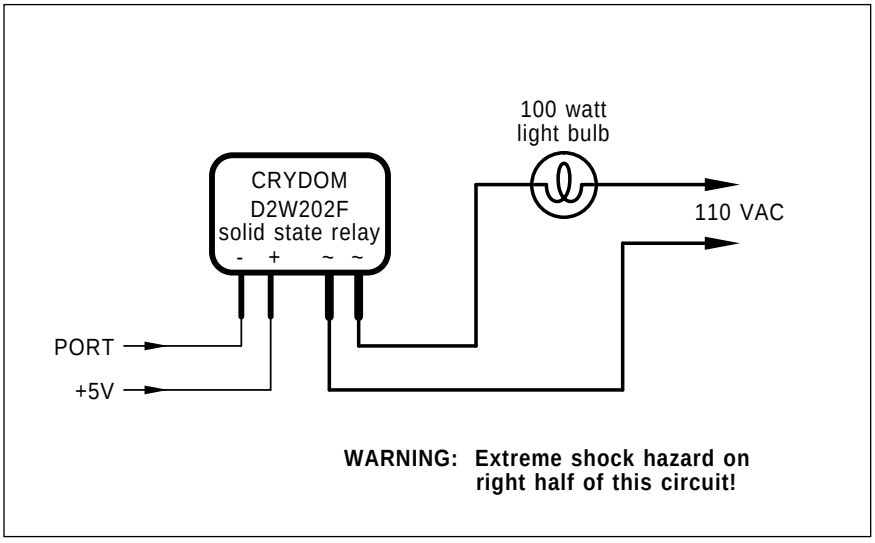


Fig. 2 – This simpler but more expensive ac power output computer interface needs only one part. Once again, a low logic input will light the lamp.

port or peripheral chip. Note that a *low* logic output *lights* the lamp, so be sure to adjust all of your software accordingly.

Yes, you could replace this four piece power interface circuit with a simpler and smaller single piece one. Figure two does show you one possibility. The only trouble is they cost around $8 or even more, compared to considerably less for the figure one circuit. The *Crydon D2W202F* shown is an *International Rectifier* product. These folks have several data books and ap notes available on these. No heatsinking is needed for lamp loads up to 100 watts.

Phase Control Dimming

The trick to your controlling the brightness of an incandescent lamp is shown in figure three. What you do is purposely and precisely *delay* the turn on of your triac each ac half cycle. If you delay until nearly the very end of the half cycle, then the lamp barely lights. Whap it in the middle and you get half brightness. Hit it right away, and you should get nearly full brightness.

The thermal inertia of the lamp's filament will average out that duty cycle and the lamp appears to light to an intermediate brightness. Since the triac is acting as a switch, it is very efficient. Note that you are working with 120 *half-cycles* per second.

Wall mounted lamp dimmers are one obvious and low cost example of ac phase control, as are all those BSR X-10 dimmer modules.

This type of phase control works out rather well for most incandescent lamps and with soldering irons and other heaters. It works sort of ok for universal motors that have brushes.

But note that phase dimming definitely should *not* be used with any fluorescent lamps or with ac induction motors. Fancier techniques are needed for any fluorescent or ac-only motor control.

One complication that's involved with computerized control is that the same optotriac isolation you used for safety also has completely disconnected you from the ac power line. You absolutely *must* know when each half cycle is coming up, or the resultant "phase slipping" will give you wildly wrong results.

So, your computer circuit will now need some interrupt or some other reference that happens 120 times per second, precisely locked to each zero crossing of the ac power line. You might rig this up with a small transformer driving a set-reset flip flop, or else by using a pair of back-to-back optoisolators or optocouplers.

Figure four shows us a simple 120 Hertz sync reference that uses yet another special type of optocoupler called an *ac input optoisolator*.

These will have two input LED's in parallel, one that "points" in each direction. One diode or the other will conduct except briefly during all the zero crossings. That Schmitt trigger inverter may or may not be needed, depending on whether you want a positive or negative sync signal.

Additional details on high power computer interface do appear in my *Micro Cookbook*, volume II.

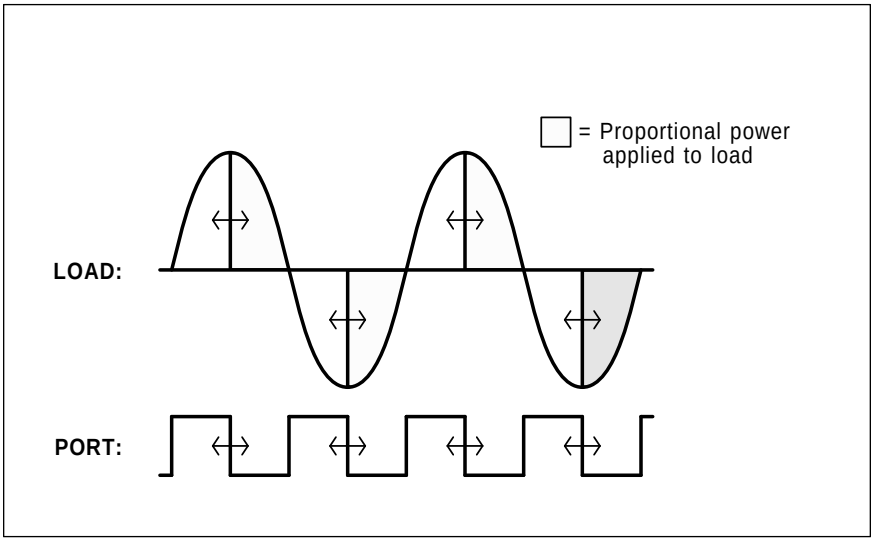


Fig. 3 – The secret to brightness control is to use a duty cycle or a "phase" modulation. Apply power early in each half cycle for maximum brightness; later for less. Use incandescent lamps only.

Some Suggestions

Many of those attempts at music controlled lighting usually will turn out anywhere from disappointing on through downright awful. The usual culprits do include threshold effects, "muddy" results, non-linearity, and a limited dynamic range. So, here are a few tips that I have gleaned over the years on what it will take to really do the job right . . .

First, you always will want to keep any supposedly off lamps just barely turned on. Besides the bulbs and the surge-sensitive triacs lasting lots longer, this might give you a better sensitivity to low level music inputs. The background level is very critical here, so watch out for any temperature drift effects.

Second, lamps and human vision perception are both very non-linear. A process called *gamma correction* is used with video cameras and CRT displays to convert any linear input signal into percevied linear brightness changes.

You similarly ought to gamma correct your visual music display. To do this, you start off with the minimum brightness and record the firing phase angle needed for the minimum perceptable lighting change. Repeat this for each successive change.

You convert this list into a linear brightness-versus-phase angle table, stored in software or in an EPROM. Note that this correction will vary with the size of the lamp and the color of your output. The goal is to have a linear input voltage or else a binary word change create a *perceived* linear output change.

Third, the dynamic range of most music is ridiculously greater than that of a visual display. So, for the best results, grab all your music or whatever *well ahead of any volume controls* and then further squash it by using a log amplifier, an automatic gain control circuit, or some sort of

a multi-voice phaselock audio tracker that would link one particular color to one certain instrument. This can get nasty and expensive to handle on a real time basis, although a comb filtering or real time digital signal processing spectral analysis surely could give spectacular results.

For live music, having a separate pickup for every instrument can work out well. In general, the more channels you use and the better their seperation, the better your final results. Use stereo at the very least.

Sixth, and finally, a static lighting display is a no-no. Either the lamps themselves or their mirrors, their diffusers, or their reflectors, should slowly and randomly reposition them- selves for variety.

Let me hear from you if you've done anything in this area or have any similar ideas.

A New Disco Chip

There's several obvious ways to go about building your own computer controlled lighting system. One way would be to model what you want on the *Commodore 64*. Another would be to use an *Apple II Plus*, which should be able to completely control even the most complicated lighting system you could possibly dream up, given some simple and very easily changed machine language EPROM driver modules.

Another route would be to go with the BSR X-10 modules, but these are rather slow acting in their dimming modes, and the costs will get out of hand if lots of lamps are involved. Multiple commands at once might also create hassles.

I'll leave details on this to Steve Ciarcia, who gave you all the BSR fundamentals way back in the September 1980 issue of **Radio Electronics,** and to his ongoing X-10 projects in his new *Circuit Cellar Ink* hacker magazine and BBS.

Or, you could use the fantastic *Mitsubishi M50734* controller chip. This jewel does have bunches of on-board I/O all ready to go and is one incredible piece of silicon. It should also be possible to work up custom dimmer/controller chips out of various PLA, PAL, or PLD chips whose costs are now down in the $3 range. Several of these alternatives would make up really great **Radio-Electronics** construction projects.

There is also a brand new *ZR2 Disco Chip* integrated circuit now available from *Alx Digital*. This is based on a programmable peripheral controller circuit and does cost around $30 in singles. It may be used singly on in groups, with or without a personal computer.

Figure five shows you some of the details. You will find twelve main operating modes, which get selected by inputting a binary word on the input lines and then resetting.

Modes one through four are for chasers or zoners with a controllable speed that may be run manually or automatically, on either a one shot or a continuous basis.

Mode five sets up a master/slave situation where a master ZR2 can serially control many others. Mode six lets you turn groups of lights on or off under command of an input control byte. Mode seven is similar, except that it accepts a wire-saving one line serial input.

Modes eight and nine are used to give UART-like features to the ZR2, with mode eight being the transmitter and nine the receiver.

Mode ten is just a simple pulse counter, while mode eleven acts as a "dc" light dimmer, based upon pulse position modulation.

Mode twelve does a full "ac" phase dimmer that can dim and brighten incandescent lamp, all at variable speeds. This mode does require a 120 Hertz power line reference input for its synchronization.

While this disco chip is certainly innovative and can do interesting things, it does seem to have several rough edges here and there. I guess I would personally opt for machine language software or else firmware instead of a dedicated peripheral circuit to do many of these tasks. The EPROM based firmware would often be far cheaper, more powerful, and more flexible.

Where can I buy "exotic" Metals and Rare Earths?

No problem, so long as you are willing to pay exotic prices for them. There's one outfit called *ESPI* and a second known as *CERAC* that will sell you most any ultra high purity element or compound. You might like to write them for their current catalog and price list.

Here's a few examples: A sheet of gadolinium or hafnium costs you $35. Indium wire costs $7 a gram, while Lanthanum Fluoride goes for $4 a gram. Neodymium Oxide is a steal at 42 cents per gram. Scandium ingots are $88 each. Zirconium wire goes for $1.70 a gram, and so on.

One obvious caution: Before you try playing with *any* exotic element or chemical compound, be sure to *thoroughly* study its properties ahead

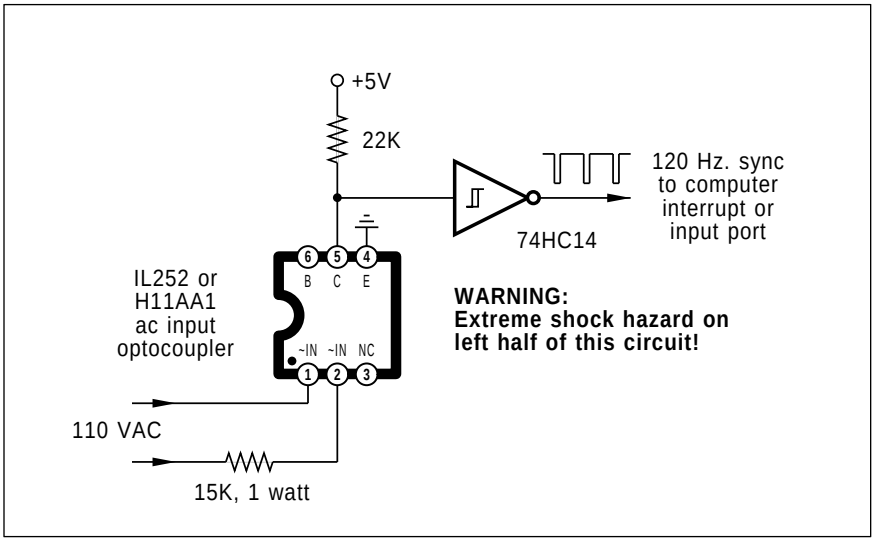


Fig. 4 – A line synchronizer input circuit is used to lock computer or controller phase timing to the ac power line. Note that this uses a special "ac input" optocoupler that lights with either input polarity.

thoroughly study its properties ahead of time, particularly the reactivity and toxicity. The good old *Handbook of Chemistry and Physics* is one obvious place to begin your research.

Another source for these elements and materials are the folks at *AESAR*.

New Tech Lit

A lot of new technical "literature" is now coming out on floppy disk, rather than printed in some catalog. *Motorola* is a major innovator here, with their new and free *Specs in Secs* data disks and selector guides.

Other examples include that free *Introduction to Programmable Gate Arrays* from *Advanced Micro Devices* and the free *MacroChip Demo* from *Ferranti Interdesign*.

The future, of course, lies in the CD ROM distribution of data and tech info. *Apple Computer* does have an unbelievably good offer here. For $15 each and one week delivery, they will line you up with some firms that can manufacturer custom CD ROM disks especially for you. The only minor gotchas are that you are limited to a trifling 80 megabytes max, that you do have to buy one hundred identical disks at a time, and that you can only do this once.

Field Effect Transistors are a good example of components which have quietly gotten better, much cheaper, and much more hacker-usable.

Siliconix has a pair of switching field effect transistor samples that are absolutely ideal hacker parts. These samples are free in singles when you phone or write for them by using a letterhead request.

The first is the *2N7000 Fetlington*. This is a small package field effect transistor that is rated 60 volts and up to 200 milliamperes of continuous current. In quantity, this beauty sells for less than a dime. It is ideal for such things as driving relays, small solenoid valves, alarms, incadescent lamps, and such.

Their second sample is the *2N7004 FETDIP*. This is a somewhat larger device with a much higher power rating. It can handle 100 volts and up to six watts of continuous power dissipation, given suitable heatsinking. The maxiumum current spec is one ampere. Their "on" resistance is a low 0.6 ohms. The uses here would include line drivers, higher power switches, current sinks, and most anywhere else you needed to switch a "fair to middlin" dc power load.

Several test circuits are included on each of the sample cards. Higher voltage versions are also available, up to the 2N7006 that is rated to 350 volts. Since negligible input current is needed, these are well suited for microprocessor control of medium power loads.

Turning to traditional data books, the "heavies" attacked in force this month. Do check into *Texas Instruments* for their new and must-have *1988 TTL Logic Data Book*, and for their *1988 Programmable Logic Data Book*. And that new *Intersil Component Data Catalog*, along with that older *Integrated Circuits for Linear Applications* from *GE Solid State*.

The *SGS-Thomson* folks have a free new *Shortform Products in Production* catalog out. Included are an incredible new variety of offbeat and oddball integrated circuits that have outstanding hacker potential.

Ten different free sample *idea kits* are now available from the *Caplugs* people, which make all types of low cost plastic caps and plugs, netting, edge liners, and such.

One obvious use is for filling and emptying caps for those laser printer cartridges. There are oodles of other off-the-wall hacker uses for these. Start of with their idea kit #12.

A *Power Measurement Handbook* has been issued by *RFL*, while data sheets on low cost ultra-violet flame detector sensors are now available from the *Hamamatsu* people.

Looking at my personal products, if you're at all into setting up your own small scale techical or craft business, do check out my classic *Incredible Secret Money Machine*. Plus our usual reminder that we are now shipping autographed copies of all our *Hardware Hacker* reprints volume II, and my Ask the Guru, both volumes I and II.

As always, this is your column and you can get some tech help and off-the-wall networking per the usual help box. Be sure to see the *Names and Numbers* directory in the rear of this volume for further info on any of the products or services mentioned.

Best calling times are 8-5 week days, *Mountain Standard Time*.

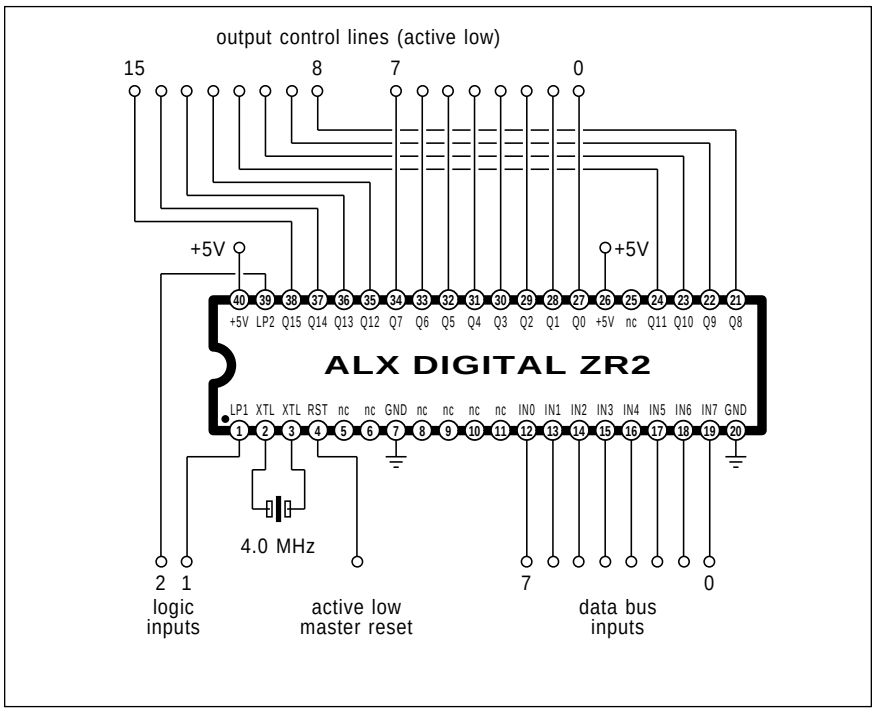


Fig. 5 – THE ZR2 "DISCO CHIP" is programmable to handle many light chasers, zoners, and ac/dc dimmers, along with other communications, counting, and control tasks. It is based on a programmable peripheral interface chip from Intel.

Don Lancaster's

Hardware Hacker

Refilling SX cartridges
Micropower regulators
More digital sinewaves
Mass teleportation card
Minimum order hassles

April, 1989

Boy, there sure has been a lot of helpline response to the solid state compass stuff we looked at two months ago. I guess I did mention that you can get fluxgate sensors off the shelf from *Radio Shack*. Meanwhile, the original "horses mouth" paper about all this is *Earth's Field Magnetometry* by W.F. Stuart, appearing in *Reports on Progress in Physics*, 1972, vol. 35, p.803 to 881. And you may also find *Recent Advances in Fluxgate Magnetometry* from the *IEEE Transactions on Magnetics*, MAG-8, #1, p.76-82 of more than passing interest.

One helpline caller has asked why magnetoresistive sensors couldn't be used. These are primarily to be used with very strong magnetic fields, and I don't think they are nearly sensitive enough for any compass use. Far and away the most off-the-wall winning entry in our fluxgate compass contest came from Dr. Dennis O'Leary who studies fish whose ears have built-in magnets. See his paper on *Magnets in guitarfish vestibular receptors*, over in *Experientia*, v. 37 (1981), p.86-87.

Several callers did give me some additional input on infrared filters. Apparently, unexposed 35 MM photo film works just fine. Years ago, I had a student learn this the hard way. He built a shaft encoder having the light transmission pattern exposed on a litho film disk. The trouble was the infrared light whipped on through the black parts just as easily as it went through the clear portions.

Some infrared response curves on their various plastics is available in a "PEL-ette" known as *Infrared Transmittance of Plexiglas Colors that are Opaque in the Visible Portion of the Spectrum*, available from the folks at *Rohm and Haas*.

Every once in a while a resource comes along which is absolutely and unquestionably in that "must have" category. This is certainly true of the *Signal* from the *Whole Earth Review* people. This is a master directory of virtually all communications resources, well done up in the style of the original *Whole Earth Catalog* and costing $16.95. No hacker can ignore this book. It is far too important.

As per usual, this is your column and you can get technical help and off-the-wall networking per the *Need Help* box. As is customary, many of the products and services mentioned do appear in the *Names and Numbers* color sidebar.

Let's start off with a loose end . . .

More on Digital Sinewaves

There was a surprising amount of interest in our recent digital sinewave stuff, and I apparently did forget to include one key technique. Thanks to Tim Green, another contest winner, for bringing this to my attention.

The idea is called *phase addition*, and its block diagram does appear in figure one. What you do is route a digital word to a D/A converter that is followed by a low pass filter, just like we did before.

Only this time, your digital word consists of the top 8 bits of a 24 bit adder/accumulator. At a constant and high clock rate, a fixed *phase increment* is added to the accumulator. For instance, a "1" input could advance the phase count so slowly that you'll get a 1 Hertz sinewave, while a "2" would give you 2 Hertz, on up to the much larger numbers which give you much higher frequencies.

Advantages of the method are that you are directly synthesizing the final frequency, which eliminates all the hunting and the noise bandwidth of phase lock loops. Thus, your spectral purity can be extremely high. There is also no bad transient whenever you change frequency 1 just a smooth and unbroken transition.

For lower frequencies, a personal computer will work just fine, and it should be trivial to generate up to several kilohertz using an *Apple II*. You can do so in one Hertz or even smaller resolution steps.

To work at any higher frequencies, speed limitations on those hardware adder-accumulators can get to be a problem. One extremely expensive source of ultra-fast chips for this is *Stanford Telecommunications*, while slower and much lower cost kits are obtainable from *A&A Engineering*. One source of additional details is the *Radio Amateur's Handbook*. Do be sure your copy is 1986 or later.

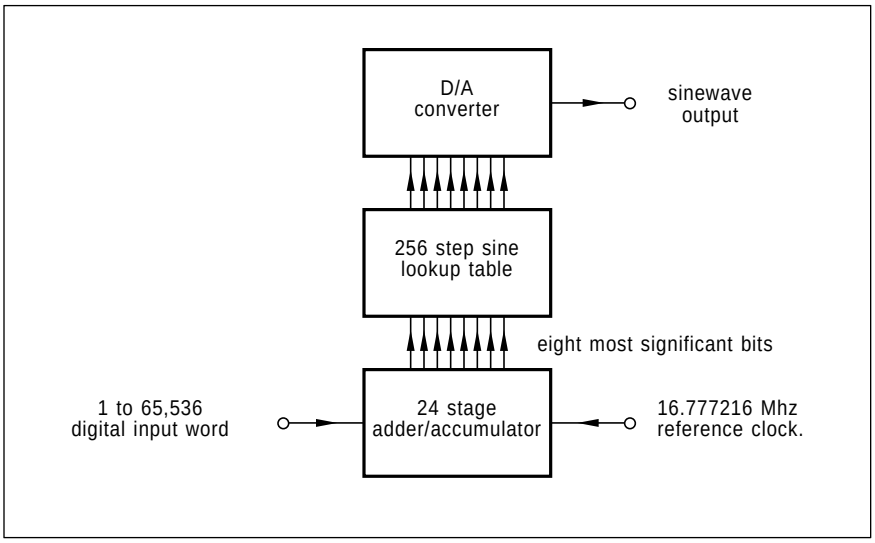


Fig. 1 – Digital sinewaves generated by phase addition. The input word sets how fast the waveform phase will advance, which in turn decides the directly synthesized output frequency. The values shown will generate from 1 Hertz to 65.536 KiloHertz in 1 Hertz steps.

Minimum Order Hassles

One of the biggest hacker helpline complaints concerns all those steep minimum orders that many of the electronics distributors seem to be insisting upon. The problem is bad and is getting much worse. How can you cope with it?

First, note that it just is simply not possible in this day and age for anyone to profitably offer the direct mail sales of electronic hardware if their average mail order ends up less than $25. Those $15 or $25 minimums or any $5 to $8 below-minimum service charges from the "new age" good guy distributors are all necessary for their very survival.

On the other hand, several of the "old line" distributors have gone as high as a $250 minimum order. Even worse yet, several of them now have an intolerable $100 per line item minimum. Which means if you want a two cent part, you now have to buy 5000 identical ones at once, or else forget it.

The *Bell Electronics* people have just garnered a ZZZ rating and moved to the very summit of my *Synergetics* black list for their unacceptably high line minimums and all their outright arrogance. (All I wanted were a few jelly bean regulators) Unfortunately, these epsilon minuses are not alone.

The sad fact is that, if you are an individual hacker, the deck gets very much stacked against you. On the other hand, this just may end up as the only game in town.

So, how can you cope with steep minimum orders? Here are a baker's dozen partial solutions . . .

(1) Plan Ahead. If you run in panic mode, you will almost always end up wasting money. Find the best dealer with the best source and the lowest minimums. Combine what you need with what you think you may need for other upcoming projects. Try to get everything from one or two suppliers, rather than a dozen.

(2) Try to always deal with a "new age" distributor, such as *Mouser*, *Active*, *DigiKey*, or *Jameco*, instead of using those "old line" houses such as *Schweber*, *Allied*, *Cramer*, *Newark*, *Bell*, or *Hamilton*.

(3) Fill out your minimum order with other goodies which you would someday like to play with.

(4) Rather than using a distributor, request free samples directly from Applications Engineering of the firm actually building the part. Use a laser printed or other business letterhead. Request only as many parts as you need, and tell them exactly what you are going to do with them.

(5) Check into your local walk-in surplus stores. Often you might find reasonable substitutes at incredibly low prices, especially on unadvertised odd lots. The savings can even make a 100 mile drive worthwhile.

(6) Build up your own personal inventory of "in stock" parts that you are likely to use in the future.

(7) Network with friends in a ham or computer club, or with engineers or techs from an aerospace company or whatever. Be able to swap parts both ways. Become a resource for the other party.

(8) Move to Silicon Valley, where all of the 24-hour convenience grocery markets also carry all the other known types of chips. No minimum. Or, if you are too far away, always be sure to try *Radio Shack*.

(9) Naturally, we would hope you would always check out our *Radio-Electronics* advertisers first for any component part. That's why we put the bingo card in the magazine. But two other great sources for oddball components are the unique *Nuts and Volts* bargain shopper and all the distress merchandisers found in that classified ad section of *Electronic News*. While the latter *always* will have steep minimum line charges, the prices are often so ridiculously low that it may not matter.

(10) Aggressively subscribe to all the electronics trade journals, such as EDN, *Electronic Design*, E.E. Times, *Electronic Products*, and/or the *Electronic Component News*. You'll find lots of free sample offers in any of these, along with unique sources of supply. As usual, you get a complete list from *Uhlrichts Periodicals Dictionary* at your local library.

(11) Acquire an enormous junk box. Or better yet, a junk room or a junk building or two. Fill them with broken tv sets, dead VCR's, or whatever else trips your trigger. A dozen cubic yards or so should do for a bare bones start.

(12) Hamfests, particularly the big regional ones, have outstanding parts bargains and zero minimum orders. Ask for full details at your local ham club, or, once again, do see *Nuts and Volts* for a listing.

(13) Combine your order with that of another hardware hacker. Or start your own "buying club".

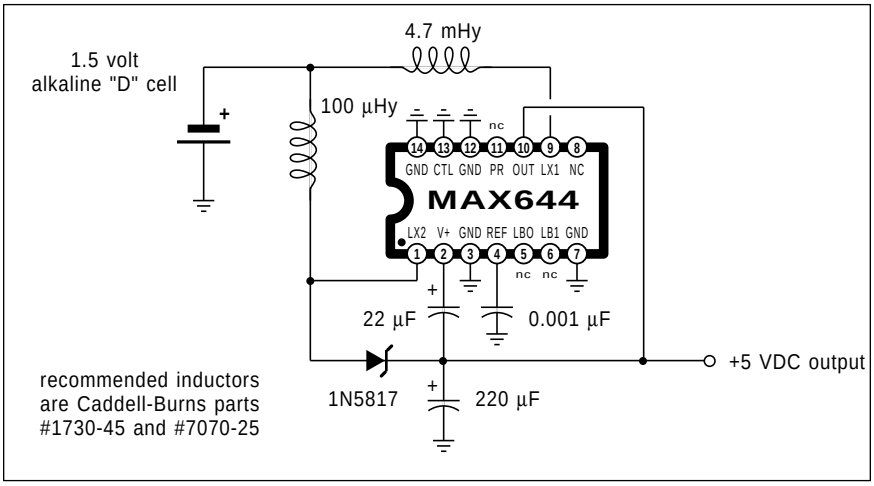


Fig. 2 – This simple switching regulator steps up a single alkaline cell to give you a fixed +5 volt output at 50 Milliamperes. An external pass transistor can be added for more output current.

Low Power Regulators

The folks at *Maxim* have added yet two more low power regulator chips to their line. The MAX644 steps up a single alkaline cell as weak as 0.9 volts up to a fixed and regulated 5.0 volts. The MAX645 gives the same treatment to a 2.4 volt lithium cell.

Figure two shows you the simple

circuit involved. The secret is to have *two* switching regulators. The first regulator generates around 12 volts or so at a very low current for internal use. This high voltage gives enough *MOS* transistor base drive to allow very high efficiency.

While the circuit is quite simple, careful selection of the inductors and the Schottky diode are needed for maximum efficiency.

The typical efficiency is in the 75 percent range. Currents up to 50 mils are directly available, while an external pass transistor may be added for higher current needs.

Refilling SX Cartridges

As we have seen in past columns, a profitable business can be built up centered around refilling toner cartridges for copiers and laser printers. Many recent hacker helpline requests have been for methods to refill those *Canon SX* cartridges as used in the *LaserJet II* and the *LaserWriter II*.

Sadly, there is now as much as a 15:1 cost penalty in per-page toner costs when using those newer *Canon* SX laser printers over the older CX engines. On the older CX cartridges, you were able to buy cartridges for five bucks out of your Sunday paper and refill them up to seven times, bringing all your toner costs down into the 0.33 cents a page range that is cost competitive with jiffy offset printing services.

Unfortunately, those SX cartridges do use a highly abrasive toner, combined with drums that are intolerably scratch sensitive.

So, while you can in fact reload SX cartridges, at present, you just can not even remotely approach those CX cartridge economics. So, do consider this a progress report where I'll bring you up to date on what can and cannot be done at the present.

While it is difficult to even get a second SX reload, you can sometimes do so with the following tricks and techniques. Firstoff, you *immediately* remove the factory toner and give it to your friendly neighborhood diesel mechanic for use as a valve grinding compound. Replace it with a good quality third-party refill toner.

Second, be certain to use a drum lubricant, such as *Pixie Dust* or its equivalent. Do a very light dusting after every refill.

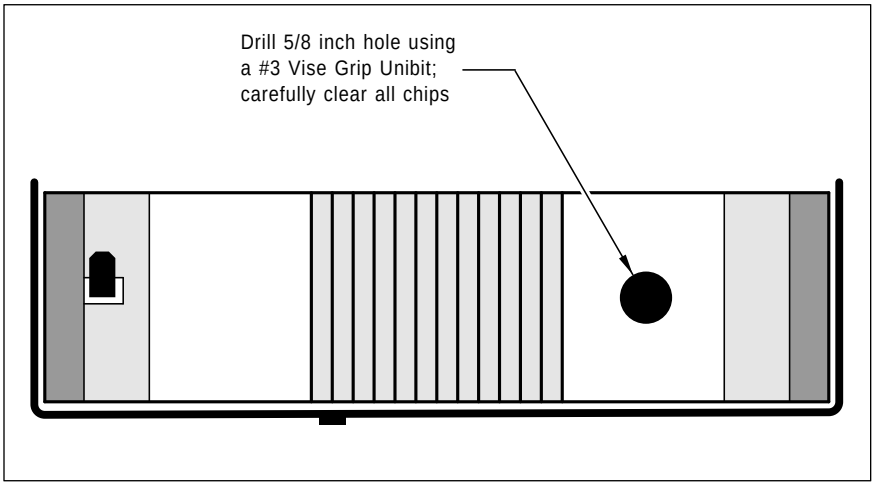


Fig. 3 – Adding a fresh toner filling hole to a SX cartridge.

There are two refilling methods, the *Punch and Go* and the *Total Teardown*. I very much prefer punch and go, since this delivers far and away the lowest per-page toner cost to the end user. We charge $22 for local SX refills. Since this is a remote rural area, I can get away with such an outrageously high price. You can do the job by yourself for as little as $7.50 and three minutes time.

The SX cartridge needs modified before you can refill it. Using a Vise Grip #3 *Unibit* and a very slow drilling speed, you drill the two holes as shown in figures three and four. Drill upside down and be very careful to remove the single chip that the unibit provides. These two holes are then capped with a nickel *Caplug* or else some very agressive tape.

There are three major steps to the refilling process. You first open the holding tank hole and carefully shake out the excess toner. Do this outside and avoid breathing any of the toner. You'll then reseal your holding tank hole, open the fresh toner tank hole, and pour in a bottle of refill toner.

Finally, you remove the old fusion wiper wand and peel and stick a new wiper pad in place.

Another tip: keep the green toner dial advanced all the way to nine for any and all rough drafts and for all internal use documents. Note that the *higher* the number, the *less* toner you will use. Cartridge life can easily be doubled with this simple technique.

I currently recommend using *Lazer Products* to supply toner, pixie dust, wiper pads, and drum recoating.

Mass Teleportation

The rate at which science and technological fact is outpacing science fiction continues to utterly astound me. Nowhere is this more apparent than in the emerging field of mass teleportaion.

The exciting center of all that has recently been happening is in that outstanding *International Journal of Teleportation and Mass Transfer*. In particular, do check out Barfoot and Gentry's tutorial material way back in Volume XVIII, on pages 1146-1198

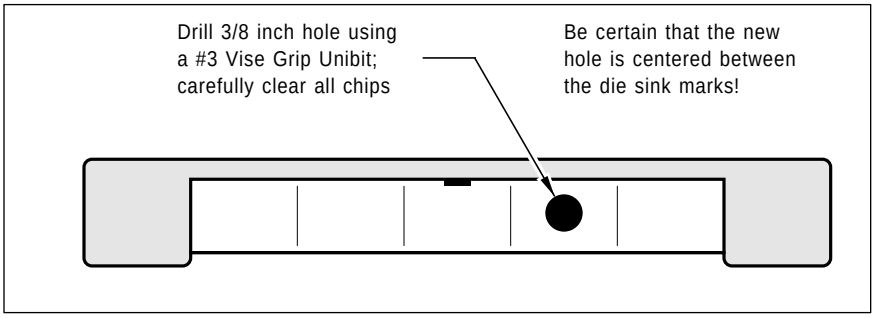


Fig. 4 – Adding the spent toner emptying hole to a Canon SX cartridge.

along with their extremely detailed bibliography. Next, for plenty of the hands-on construction details, check out Checiski, Colcord, and Elden's medium budget project on pages 1245-1277 of the same issue.

It sure is refreshing to see a very scholarly journal that always remains simple, practical, and yet quite easily understood by lay people. It looks like the technology to watch is the *quark-muon* dissociation and regeneration process.

So, I guess I was not too overly surprised when Marcia Swampfelder shipped me her latest two peripheral cards for the old Apple II Plus, her MTT-T1 mass transferrence transmitter, along with her MTT-R1 mass transferrence receiver. Marcia is a tad on the conservative side, so she insisted on using the illegal monitor entry points that precludes the use of these cards on newer Apples or other personal computers.

The pricing is rather attractive at $68.50 for the MTT-T1 and a mere $43.50 for the separate MTT-R1. You can order direct from Marcia.

Anyway, you first plug your transmitter card into one Apple II Plus and as many as four receiver cards into four receiving Apple II Plus computers. Any object that gets placed in the transmitter's dissociation chamber then will appear reconstructed in the receiver's regeneration chamber.

The effective range does depend on the telephone line in use, but for your average quality voice grade line, you can teleport objects as far as 500 miles using one receiver, 200 miles using two receivers, 100 with three, and 50 miles with four receivers. The poorly understood methodology of *conjugate phase decongruence* does prevent you from reliably using more than four receivers, regardless of the distance. Even on local loops.

The Apple power supply and baud rate considerations both limit the size of the teleportation chambers. Those chambers found on the MTT-T1 and the MTT-R1 are slightly larger than a quarter. In the usual demo of these cards, you insert a quarter into the chamber on the MTT-T1 card, and it will reappear intact approximately 12 minutes later on the MTT-R1.

For a real "Golly Gee Mr. Science" demo, you permit four regeneration cards to serve each dissociation card. The single quarter you placed in the dissociation chamber will simultaneously reappear in all four of the receiving cards, again in the twelve minute dissociation-regeneration interval. Put another way, the quad demo returns a dollar in change for every quarter that is invested.

Figure five shows you the MTT-T1 transmitter card. The teleportation chamber is optical fiber coupled to an *Atascotia Industries* 100 milliwatt tunable ultra-violet solid state laser. I don't know whether the $2.75 price or the 67 percent optical efficiency is the most outstanding feature of this new component. The rest of the card consists of all the usual RAM, ROM, CPU, and I/O stuff, all done up in Marcia's highly conservative style.

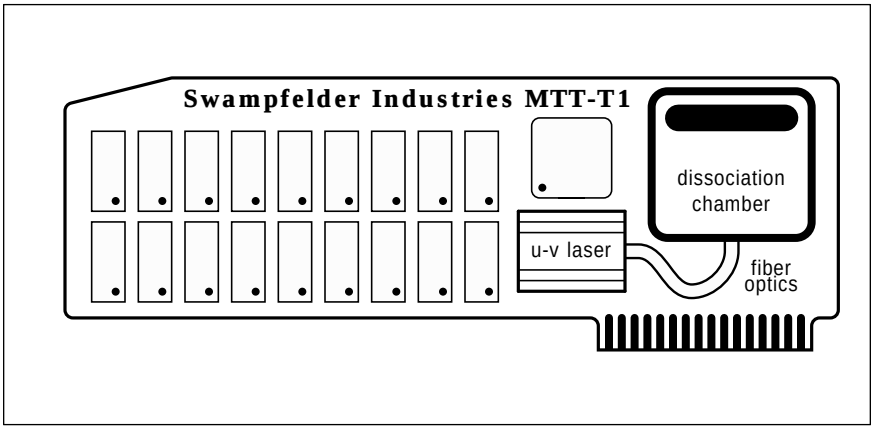


Fig. 5 – Pictorial of the mtt-t1 mass teleportation transmitter unit for the Apple II Plus. The solid state 100 milliwatt ultra-violet laser chip gets optical fiber coupled to the dissociation chamber. The telephone connection is made on the other side of the card.

Marcia reports that virtually all of her current production is going to all the importers of specialty herbs and spices. Her new teleportation system eliminates all of those long delays at customs, besides allowing her users to set all of their own international currency exchange rates.

You can contact Marcia directly for additional info.

New Tech Literature

A new *Microelectronic Data Book* just arrived today from *Mitel*. It is chock full of telecommunications chips, and includes bunches of useful ap-notes. Two other recent arrivals are the *Linear Circuits Applications* from *Texas Instruments*, and that *MOS Products Catalog*, from *Gould*, who recently bought out *AMI* and all the chips described in the book.

Some interesting new strain gauge products are now available from *BLH Electronics*. In particular, their SR-4 should be useful for weighing scales or whatever. And *Sharp* has a new *LCD Units* booklet on liquid crystal displays and their drivers.

Tektronix has a new *TEK Direct* catalog and several free videotapes out. Their oscilloscope prices do start under $700, and are much better than those of any other manufacturer.

Unusual and quite high quality audio kits are available from the *Old Colony Sound Lab*. As a caver who exclusively uses carbide for light, I guess I've disqualified myself from commenting on the apparent stupidity of still continuing to use vacuum tubes in this day and age. Oh well.

ColorEase is an unusual and quite messy process that lets you create your own full color "real ink" instant transfers that may be professionally applied to virtually any surface.

Two interesting new trade journals include *ID Systems* on bar codes and such, along with *Sensors*, intended for the robotics crowd.

Turning to my own products, if you are at all into designing active electronic fiters, check out my *Active Filter Cookbook*. If you are into high quality text or graphics of any style, be sure to look at all my PostScript stuff, especially the *PostScript Show and Tell*. Finally, remember that we now have fully updated and edited *Hardware Hacker* bound reprints.

Don Lancaster's

Hardware Hacker

May, 1989

Those SAW devices
State variable filters
Phase plane plotting
Call progress detectors
Low frequency resources

We seem to be once again moving into a second new golden age of hardware hacking, as more and more people are discovering that there is an incredible variety of new and easy-to-use hardware goodies out there. Its also getting rather painfully obvious that hardware and software have to work together in this day and age, rather than standing alone.

As you do know by now, the staff here at **Radio-Electronics** is in the process of resurrecting the original **Popular Electronics**, and fully intend to revive both the spirit and intent of the original. You will also soon be seeing some major layout and content improvements right here in **Radio-Electronics** as well.

Besides us, and our erstwhile *Modern Electronics* competitors down the street, and all of those various ham radio and CB magazines, you'll find three new and important hardware hacking resources. Steve Ciarcia is going great guns with his new *Circuit Cellar Ink* magazine. *Heathkit* has a major new hobbiest magazine in the works. And, *Nuts and Volts* is a little high energy shopper aimed squarely at hardware hacking.

While I have mentioned this a time or two before, no serious hardware hacker can afford to ignore any of the electronics trade journals, including *EDN*, *Electronic Design*, *Electronic Products*, *EE Times*, and *Electronic Components News*. As usual, you'll find a complete listing of *all* of the popular trade journals in *Uhlrichts Periodicals Dictionary* found on the reference shelf at your local library.

Once again, this is your column and you can get technical help and off-the-wall networking per the *Need Help?* box. Your best calling times are 8-5 on weekdays, *Mountain Standard Time*. As per usual, I have gathered most of those *Names and Numbers* together into one sidebar. Contact these people directly for more info.

This month, we have a mixed bag of off-the-wall topics. Let's start off with some…

Call Progress Detectors

How can an electronic circuit tell if a phone call ever gets successfully completed? This is very important for fax machines, for security and alarm devices, auto-dialers, unattended BBS communications, and any place else that you want some electronics to be able to complete a call without any outside help.

Identifying just what is happening when goes by the name of *call progress detection*, and the single chip integrated circuits that handle this are called *call progress detectors*.

Three leading manufacturers of the call progress detector chips include *Teltone*, Signetics, and those *Silicon Systems* folks. We will use the chips from *Silicon Systems* here.

Call progress gets measured by the presence of one or more *supervisory signals* on the phone line. There is the *dial tone* that tells you that the line is ready to use, the *busy signal* that tells you a call can not be completed, the *ringback* that simulates the sound of the phone at the other end ringing, and finally, an obscure *reorder* signal that tells you the call only went halfway through and has to be repeated.

Two methods of detecting a call progress signal are by the *frequency* and their *cadence*. For the most reliable detection, both of these should be used together.

Figure one does show you all the standards for those *new* or *precise* call progress signals. These will work for most people most of the time. The dial tone is a continuous mix of 350 and 440 Hertz sinewaves. The busy signal is a gated mix of 480 and 620 Hertz, with the cadence of half a second on and half a second off.

The ringback is a gated mix of 440 and 480 Hertz sinewaves, having a cadence of two seconds on and four seconds off. Finally, that odd reorder signal is a gated mix of 480 Hertz and 620 Hertz signals, with a cadence of 0.3 seconds on and 0.2 seconds off.

Figure two shows you a typical

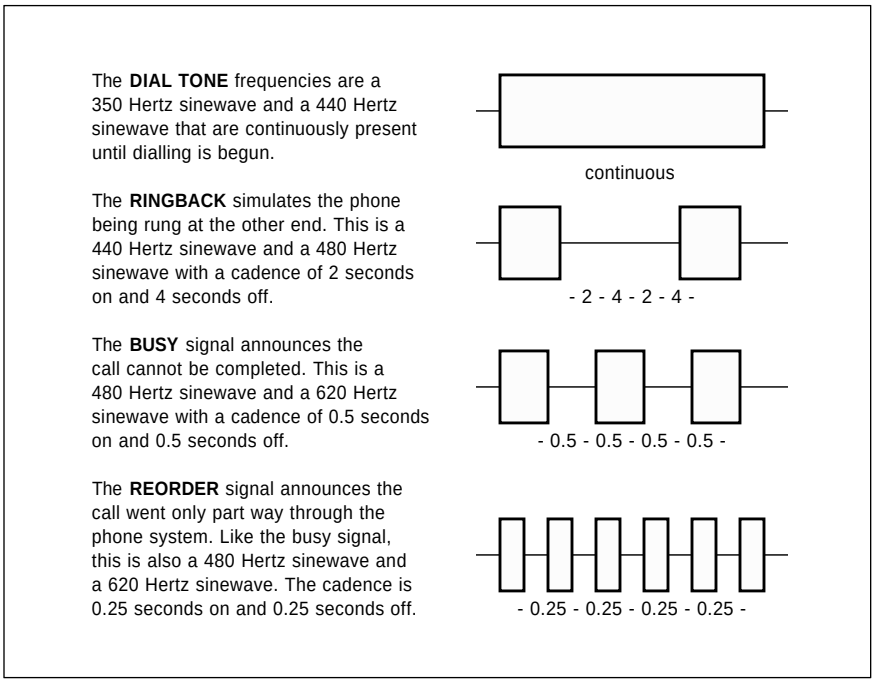


Fig. 1 – TELEPHONE CALL PROGRESS signals can be detected by both their frequency and their cadence. Here are all the US standards for the "precise" or the "new" call progress tones.

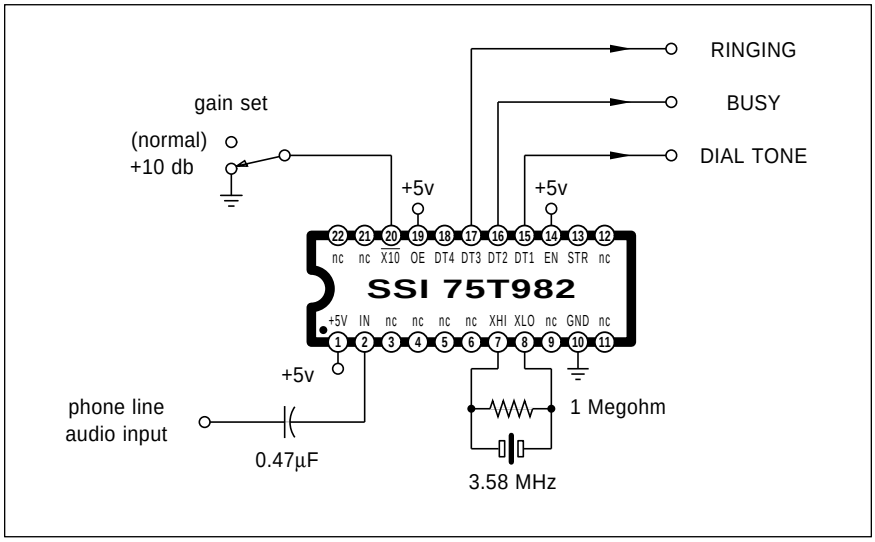


Fig. 2 – A CIRCUIT TO DETECT the "new" or "precise" call progress signals. This is a Silicon Systems chip; others are available from Signetics or Teltone.

circuit which uses the 75T982 Call Progress Detector. The phone line is capacitance coupled into your input. The sensitivity can be increased by ten decibels by using that XRANG input as shown. Clocking is by way of a built-in oscillator using a low cost color tv crystal. You will see four separate output lines for dial tone, ringing, busy, and reorder. There is a separate *strobe* output on pin 13 that tells you if *any* output is active.

There is an older and simpler chip known as the 75T980 that works with both old and new call progress tones. However; its detection is not nearly as reliable, and an external cadence measurement must be made to sort out the progress commands.

Pricing is around $7 for the 980 and $12 for the 982 in the small hacker quantities. For additional use details, do see the *Communications Products* data book from *Silicon Systems*.

LOW FREQUENCY RESOURCES

Low Down
Longwave Club of America
45 Wildflower Road
Levittown, PA 19057

$12 per year

1750 Meters Update
% Jim Ericson
226 Charles Street
Sunnyvale, CA 94086
(408) 773-8947

$10 per year

Speleonics
% Frank Reid
PO Box 5283
Bloomington, IN 47407
(812) 339-7305

$4 per year

Northern Observer
% Herb Balfour
91 Elgin Mills Road West
Richmond Hill, Ontario
CANADA L4C 4M1
(416) 884-5355

$12 per year

BCRA Radio Group
% Phil Ingham
49 Highfield Road
Farnworth Bolton
ENGLAND BL4 0AH
(0204) 791918

$10 per year

Fig. 3 – The low radio frequencies below the broadcast band support all sorts of interesting time and frequency services, navigation aides, cave rescue, the mine safety, metal location and treasure finding services. Here are the main hacker low frequency newsletters.

Low Frequency Resources

There are all sorts of interesting things going on in those low radio frequencies below the AM broadcast band. Look closely, and you will find time and frequency standards, precise navigation systems, communications devices for cave rescue and for mine safety, metal locators, treasure finders, and bunches of other interesting and oddball stuff.

As you might suspect, there are some great little newsletters out there that support any hackers with strong interests in low frequency communications. Figure three gives you a list of the "top five" of these resources.

Of these, far and away my favorite is *Speleonics*, and many thanks to their editor and publisher Frank Reid, for putting me on to the others.

And, Hey. These are all volunteer labor-of-love nanobudget setups. So, either subscribe outright or else send them a buck and a SASE with any of your inquiries.

SAW Devices

There sure seems to be a lot of hacker interest in the *SAW*, or *Surface Acoustical Wave* devices. Sadly, all of these are usually custom devices offered only in large quantities. Only rarely will useful devices show up on the surplus market. And it does take some smarts to properly apply them.

At any rate, a SAW device consists of a transmitting transducer and the receiving transducer mounted upon a suitable substrate. That transmitter will create a surface wave that can travel across the device over to the receiver. By carefully controlling the layout pattern of the transmitter and the receiver, you can create a fancy filter, a delay equalizer, or a sophisticated radar signal processor.

The SAW devices are very popular for television and for cable system filtering, since they can give a fancy response curve in a very small package at low cost. Most important of all, they do not require any alignment, calibration, or adjustment to get or keep the desired response.

These SAW filters are inherently

lossy. Some are offered with built-in amplifiers and impedance matchers, while others are nothing but the SAW device itself.

A typical SAW device might get used as a 44 Mhz filter that can go between the television tuner and its intermediate frequency signal processing. Another use is for the vestigal sideband filters used by some cable tv and satellite systems.

One quantity source of low cost SAW devices is *Plessey Signal Technologies*. All of their models SW302, SW303 and SW304 are typical channel 2, channel 3 and channel 4 vestigal sideband filters which sell for around $2.50 in thousand lots.

Plessey's minimum order is 500 identical pieces. I know of no retail or low volume source, except as the catch-as-catch-can surplus in such places as *Nuts and Volts*. Do let me know if you find any.

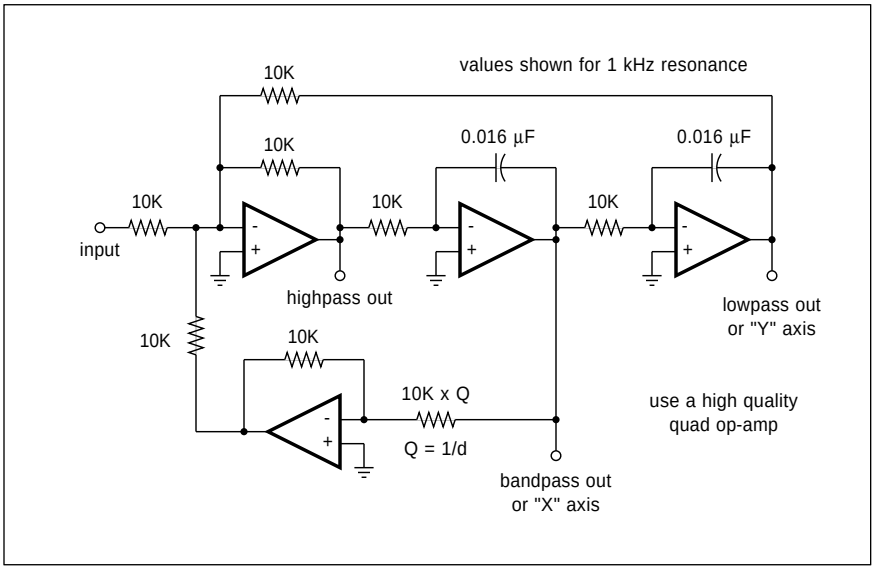


Fig. 4 – THIS STATE VARIABLE ACTIVE FILTER can give you lowpass, bandpass and highpass outputs, and is a good "workhorse" circuit for both low and high Q uses. This is also a handy test circuit for exploring phase plane plots on your own.

An Active Filter

Active filters form a class of electronic devices that use operational amplifiers, resistors, and capacitors to replace all the cumbersome, lossy, and expensive inductors needed in all the traditional filters. These days, active filters will compete against switch capacitor integrated filters and digital signal processing techniques, so their use has pretty much peaked. Especially at high signal levels.

You'll find lots of hands-on active filter design details inside my *Active Filter Cookbook*. Let us look at a typical "workhorse" active filter circuit that has a high "Q", high stability, a minimum interaction, and easy tuning. It is known as a *state variable* filter and simultaneously could give you a low pass, band pass, and high pass output pins.

Figure four is an example of a 1 Kilohertz *state variable active filter* that uses a quad op-amp to produce a single low to high "Q" pole in the audio range. You adjust your frequency range by changing either the resistors or the capacitors, keeping their ratios constant. The "Q" gets adjusted with the resistor as shown. Usually, several of these circuits are cascaded to make a fancier overall response function. Full details appear in the book.

I'm showing you this circuit here since we will need to use it just as soon as we start talking about . . .

Phase Plane Plots

Every now and then, some idea will just sit there, quietly blorking away on all of those back burners of hackers everywhere. Until the time gets ripe to do new and exciting things with it. Let's take a look at one of the oldest of hardware hacker concepts, and see where it is going today and in which direction we can try and shove it in the future. For fun or cash.

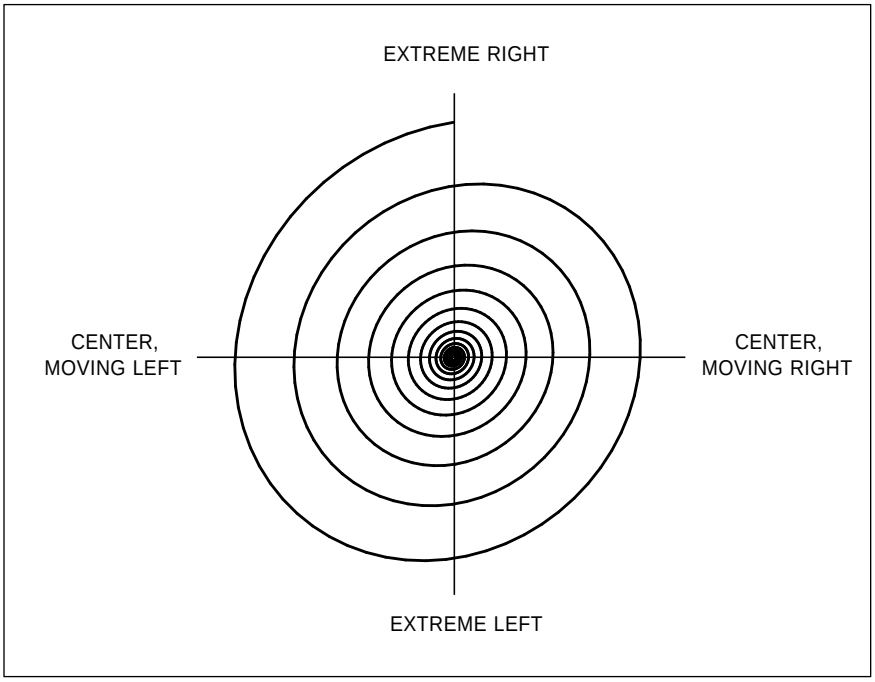


Fig. 5 – The phase plane plot of a damped pendulum. Phase plane plots do have important uses in response curves, system stability, chaos theory, and for many unusual artistic effects. Note that time is a parameter that advances inward along the path of the phase plane plot.

I am speaking of *phase plane plots*, an extremely old graphic technique that today can be extended into some stunning new art forms as well as used to create all sorts of new age toys and gadgetry.

A phase plane plot is simply a two or a three dimensional plot of the amplitude versus the phase angle of some value of some physical or abstract system. Time is a parameter that goes *along* the curve. As one example, say we gave a damped pend- ulum a shove and then plotted its phase angle versus time. We would get the spiral phase plane plot of figure five.

We do get a spiral because of the damping. The greater the damping, the faster the swings will die away and the sooner the pendulum will come to rest. Should we have zero damping (or infinite "Q"), we would create an oscillator whose phase plane was a continuous circle. Should the system receive some energy from an outside source, we might even end up with *negative damping*, and the spiral would expand towards infinity, rather than contract. At some point, we will limit against some physical constraint of the system and somehow box ourselves in. Or else self-destruct.

By the way, the apparent distortion in figure five is quite real. Your eye is expecting circles, and that motion towards the center seems to squash things slightly. This will get far more obvious as the damping goes up.

One of the oldest of phase plane plots is called the *Lissajous* figure. Back in the days when oscilloscopes did not have any decent time bases in them, you measured frequency by inputing an unknown frequency on the x axis and a known one on the y axis. Any time the two frequencies would be some exact fractional multiple of each other, you would get a stationary pattern on the screen. Figure six shows you a Lissajous figure of two sinewaves which are related in frequency by a factor of precisely 3:2.

Note that we are plotting an "X" amplitude against a "Y" amplitude, and that time is a parameter that will move *along* the curve. This is what phase plane plots are all about.

Yes, there are many serious uses of phase plane plots. Some of these do involve the system stability of servomechanisms and power systems. An exciting new study area of the phase plane plots involves *chaos theory*. The phase plane plots can reveal areas where a physical system will behave rationally and other areas where it will behave chaotically.

One of the most famous of chaotic phase plane plots is called the *Lorenz Attractor*, otherwise known as the "owls mask". A good starting point to explore this fascinating subject is *Chaos; Making a New Science* by James Gleick. In fact, it seems that many classes of a physically chaotic behavior end up being described by one of a very few phase plane plots known as *strange attractors*. There is a very distinct possibility that such chaotic things as weather and stock market prices are ultimately controlled by these strange attractors. And that gets heavy fast. Real fast.

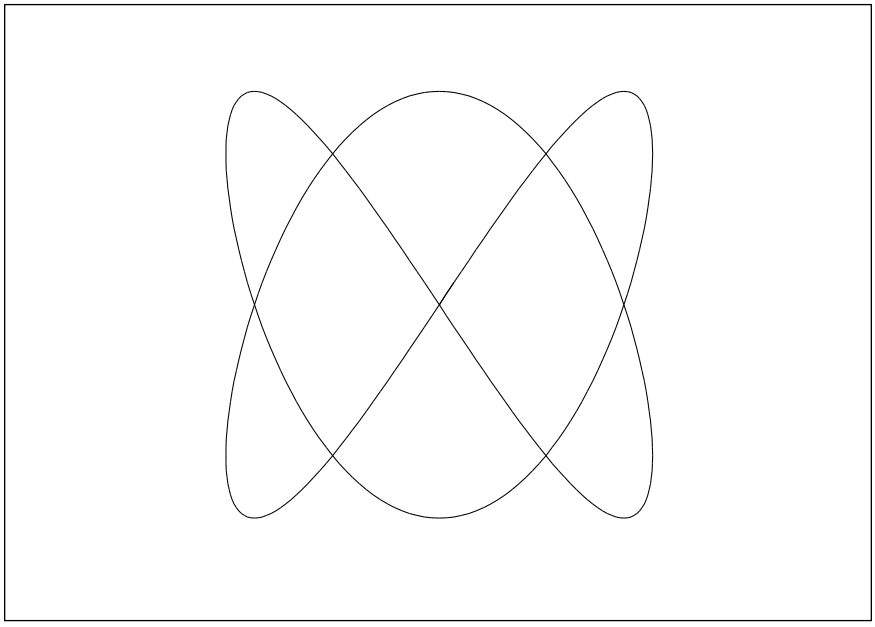


Fig. 6 – The Lissajous figure is the oldest of phase plane plots. The two sinewave frequencies shown here are in a ratio of 3:2.

I guess I first really got into phase plane plots back when I was writing my *Active Filter Cookbook*. We had built the circuit of figure four up, and inadvertently connected the real and quadrature outputs to the "X" and "Y" inputs of a scope.

We input some music and then the whole engineering department sat fascinated for hours staring at those wondrous and beautiful waveforms. Things did get even more interesting when we substituted a low frequency function generator for all the music. Which gave you several stunningly artistic patterned objects. Many of these appeared in chapter ten of my *Active Filter Cookbook*. I called these waveforms *quadrature art.*

I invite you to take the figure three circuit, hook it to a scope, and input some music or a function generator and see what you come up with. At the time I did this, visions of exciting newer color organ and psychedelic lighting style toys danced through my head. Reality struck when I did realize that the oscilloscope was es- sential at that time. And not enough hackers had scopes to bother with.

But today we have low cost oscilliscopes. We have color computers everywhere. We have plotters and high resolution printers. We have cameras and VCR's. And, above all, we have that incredible new *PostScript* graphics language that I am so keen on. We also now can use an imaginary, rather than all real-world inputs. In just the same way that synthesizers can routinely generate sounds that are nearly impossible to do with a real acoustical system. So now is the time to fire up the old phase plane plot and convert it into some brand new art forms or some exotic "new age" toy.

Ferinstance, figure seven gives us an abstract art PostScript phase plane plot I recently whipped up. You can do

the very same thing with the BASIC language and most any old computer, printer and display screen.

So, for the first of this month's two contests, do something with a phase plane plot and tell me about it. We'll have the usual dozen or so *Incredible Secret Money Machine* books for the better entries, and an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two awarded to the best of all.

Write or call me if you need the PostScript listing for figure seven. Or want to know more about PostScript itself, that fantastic new language.

New Tech Literature

Surplus Traders are the lean and mean channeled reincarnation of the old *ETCO* operation. You will find some outstanding bargains in their many flyers, including nine cent tilt switches and thirty dollar CP/M computers. Their $24.50 *Hitachi* VCR front ends look like they will be most useful for receiving television on a computer monitor. The stock is number RE011. More on this whenever.

For "raw iron" surplus, check out *Borden's Surplus Center*. These folks carry big mutha hydraulics, motors, steppers, pneumatics, and such, all at really great prices.

A free sample packet of porous plastics is now available from *Porex Technologies*. While both opaque and structurally sound, you could freely blow air or water through these while attenuating noise. As a second contest this month, just tell me about any new or unusual use for a low cost porous plastic. Speaking of plastics, one good source for plastic gears and belts are the people at *Plastock*.

From *Hewlett-Packard*, the latest release on their great *Optoelectronic Designer's Catalog*. From *Teledyne*, a new and free *Data Acquisition IC Handbook* that includes a bunch of useful ap-notes. From *Silicon Systems*, a *Communications Products* data book. And, from *Supertex*, the latest catalog on CMOS and DMOS devices, encoders, and their smoke detector chips.

If you are into computer aided design, one of the latest of the free trade journals is *MicroCAD News*.

Turning to my own products, for much more info on both active filters and phase-plane quadrature art techniques, check out my *Active Filter Cookbook*. And, yes, we have custom book-on-demand bound reprint sets of all my *Hardware Hacker* columns that you have seen here, and all my *Ask The Guru* reprints from my sister column over in *Computer Shopper*. For more on PostScript, we also do stock all of the Adobe books and Apple's new *LaserWriter Reference*.

Let's hear from you. ✦

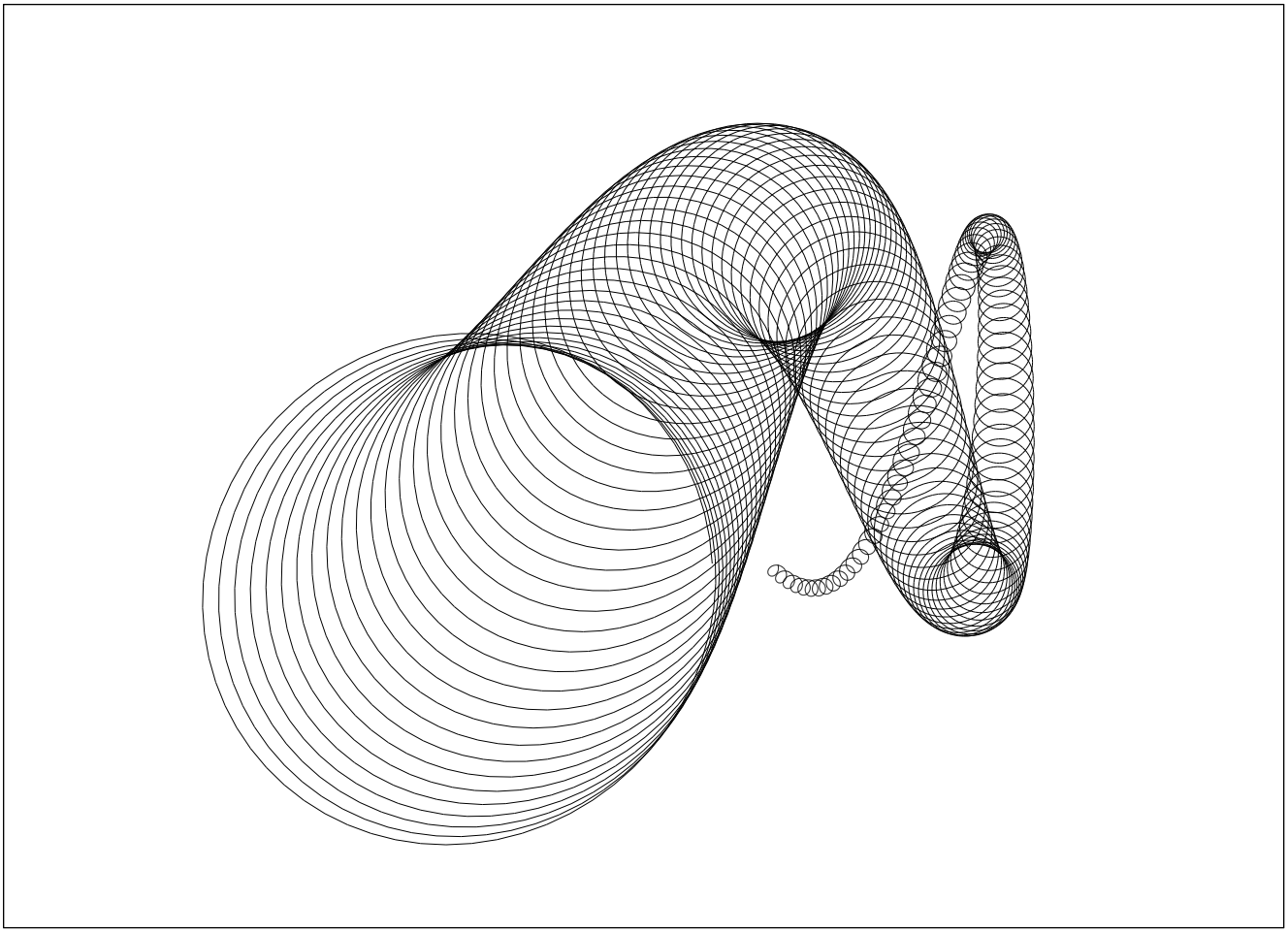


Fig. 7 – A totally ficticious phase plane plot simulated by using the PostScript page description language. Similar results can be gotten with most any language on most any personal computer.

Don Lancaster's

Hardware Hacker

June, 1989

Soup cans full of chips
Sensors and transducers
Digital audio front ends
Starting your tech venture
Delta-Sigma A/D conversion

There sure was lots of reader response to our big HDTV contest we ran a few issues back. As expected, most of you strongly did support the flushing of NTSC compatibility at the earliest possible opportunity.

Fortunately, there is a new HDTV consortium starting up that does include such outfits as *IBM*, *Apple*, *Hewlett Packard*, *Compac*, *Tektronix*, and a few others. Together this crew should have enough clout to spank both the FCC and the networks and send them all off to bed without any supper, if they continue to insist on all of their pathetically limiting and mindlessly short-sighted substitutes for genuine digital HDTV.

Here, more at less at random, are several of the more interesting HDTV points that many of you made:

"The concept that HDTV will only be good for the 40 inch and higher screens is not only totally absurd but completely misses the point. The key future of HDTV lies in closing the gap between computing and home video displays. Any time that HDTV text is involved, all of the differences will be obvious on a two inch screen, let alone a larger one… "

"Twelve years ago, a video display device in the home was only used to watch network tv. Today it can do a dozen major functions, the most important of which do include personal computing, video games, those cable services, and for watching videotape rentals. And, twelve years from now, there will likely be hundreds of possible uses, the most significant of which will probably be a fax mail delivery service…"

"The phone company should be a big player here. They recently did get approval for a total fiber optic phone network, which ultimately just might make them the primary broker for home HDTV material. The obvious advantage here is that you have a full bandwidth, two-way comm setup in which each customer's needs can be individually provided for… "

"There *already* are several million HDTV display devices in consumer's homes today. They are called *NEC Multi-Sync Monitors*, and there will probably be ten or fifteen million of them around by the time the first of the real HDTV receivers roll off the production line. To ignore these is sheer lunacy…"

Once again, many thanks for your input on this. One interesting way of getting a good handle on any major technological change is to look into another one from long ago and far away. To this end, you might find *The Electric Interurban Railways In America*, by George Hilton and John Due, to have an awful lot more to say about HDTV than you'd first expect. Stanford University Press, 1964.

Once again, this is your column and you can get technical help and off-the-wall networking per the *Need Help?* sidebar.

Our real biggies this month include some ready-to-use, sanely priced, and rather hacker-friendly digital audio front ends. But first…

Starting a Tech Business

Step number one of any serious hardware hacking is to create your own tech venture having all its own letterheads, business cards, mailing address, answering machine, and a bank account. There are simply too many doors that get slammed in your face if you omit this essential step.

Among zillions of other benefits, it is far easier and ridiculously cheaper to get the free trade journal subscriptions, samples, data books, and ap notes if you do appear to be professionally competent.

These days, it can be very fast and

The **CSZ5126** is an older 16-bit and 50 kHz two-channel successive approximation A/D conversion chip. It is self-calibrating and needs no sample-and-hold, but still requires an input anti-aliasing filter.

The companion evaluation board is model **CDB5126/5101**, and can be used as a nearly complete stereo audio front end. Both serial and parallel digital outputs are available, with a choice of internal or external clocking easily selected.

The **CS5501** is a 16-bit and 10 Hertz single channel Delta-Sigma A/D conversion chip intended for precision DC measurements. It is a total conversion subsystem that includes a powerful internal anti-aliasing filter, sample and hold, and auto calibration.

The companion evaluation board is model **CDB5501**, and can be used as a complete precision instrumentation front end. The output serial data is easy to interface to most any modem or computer.

The **CSZ5326** is a new 16-bit and 50 kHz two-channel Delta-Sigma A/D conversion chip. It is a total conversion subsystem that includes a powerful internal anti-aliasing filter, sample and hold, and features auto calibration. The impressive specs include a dynamic range of 95 decibels, signal-to-noise of 106 decibels, 0.001 decibels of passband ripple, and 0.0015 percent of total harmonic distortion.

The companion evaluation board is model **CDB5326**, and can be used as a complete high performance stereo audio front end. Both serial and parallel digital outputs are available, with a choice of internal or external clocking.

Fig. 1 – CRYSTAL SEMICONDUCTOR has all of these very impressive new A/D converter chips and evaluation boards out. These can be used as stereo digital audio or as precision instrumentation and measurement front ends.

and cheap to form your own tech venture. What you do is set up a new business entity that is called a *simple proprietorship*.

To start, pick a name and register it with your state's Secretary of State as a tradename. The name must not be in use, must not be deceptive, and must not be obscene. Beyond that, anything usually goes. Stay a tad on the "vague-but-unusual" side, so you can use that same name for different purposes and are unlikely to become confused with anyone else. The cost of trade name registration out here in Arizona is around $15 for five years. The price varies with the state, but usually it is no big deal.

Next, rent yourself a post office box and on the "Who uses this box?" form, put in your name and the name or names of your venture. Open up a new bank account and fill out their alias card the same way. Get a *for deposit only* rubber stamp with both your own and the company name.

For stationary, simply use a PostScript speaking laser printer to work up all your own letterheads, business cards, logos, invoices, and shipping labels. This is fast and cheap. More details on all this are ongoing in my other column that's over in *Computer Shopper* magazine as well as in my *Ask the Guru* reprints.

With a proprietorship, many of your hardware hacking expenses can easily become fully tax deductable, provided a few common sense rules are followed. Your business is expected to show a profit two years out of five. It is expected to be conducted as a business as opposed to a hobby. Any home office or lab space must be clearly and exclusively dedicated totally and absolutely to the goals of your intended venture.

All of the deduction rules on home office space have been tightened up considerably, owing to the previous abuses. But if your home space is the *exclusive* and *primary* place where all these activities take place and is in no way for the convenience of you or your employer, you should rightfully claim this deduction.

The primary goals of your venture also have to be legal and must *not* be centered on the management of your investments. Above all, accurate and professional records must get kept, consistent in detail with what others would do in a similar enterprise.

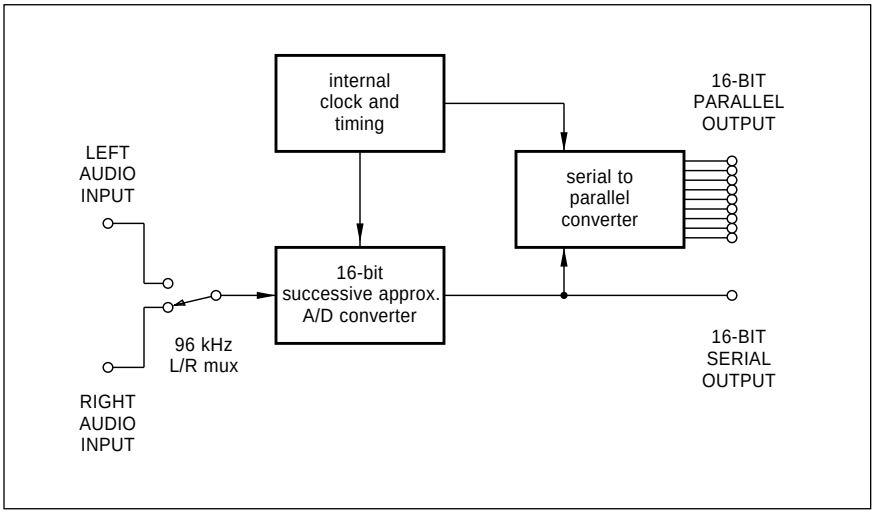


Fig. 2 – A SIMPLIFIED BLOCK DIAGRAM of the CDB5126 stereo audio A/D front end board. Because of a factory tested layout, nearly all of the usual black magic involving ground noise, shielding, and guarding has been done for you.

With careful records, you can also tap other major tax benefits such as depreciation, investment tax credit, minority and female business credits, and even those research and development tax credits. The obvious way to start all this is with one each of *every* free tax booklet from the IRS.

Lots more info on this sort of thing does appear in my *Incredible Secret Money Machine* book.

Digital Audio A/D Front Ends

There is a spunky little integrated circuit house way down in Texas by the name of *Crystal Semiconductor*.

The folks here are totally upsetting the entire A/D converter industry.

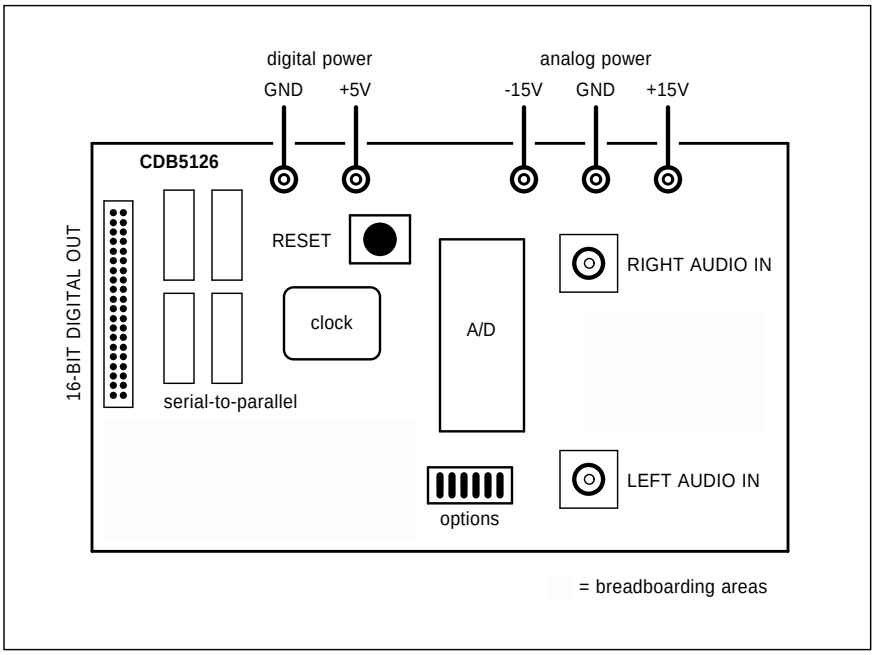


Fig. 3 – THE LAYOUT OF THE CDB5126 stereo audio front end. You literally squirt your stereo audio into the right side connectors, and 16-bit digital bits and bytes pour out the left. Note that digital +5 volt supply power must be applied AFTER the analog power or serious damage can result.

What they produce are some totally revolutionary and yet moderate cost single chip A/D conversion systems and "plug and go" evaluation boards. What this means is that at long last there are some instant and professional quality digital stereo audio front ends that are hacker friendly and sanely priced.

As we've seen in previous issues, it is real hard for your typical hacker lashup to yield even 9 bits of A/D resolution, let alone 16. The new eval boards eliminate all of that black magic involved in proper shielding, grounding, and guarding. While by no means a beginner project, these boards will let an advanced hacker quickly digitize first quality stereo audio to 16 bits and beyond. For just about any use at all.

Figure one summarizes three of their more interesting chips and their supporting evaluation boards. The chips are typically priced in the $16 to $50 range, while their ready-to-use evaluation boards run around $150 or so, including the needed A/D chip.

The oldest of these three chips is called the CSZ5126, and is included in the CDB5126 evaluation board. A simplified block diagram of the board is shown in figure two, and a simplified pictorial appears in figure three.

What you have here is basically a 16 bit and 100 kHz Analog-to-Digital converter. It uses the traditional successive approximation method, but uses capacitors, rather than resistors, in a *charge rebalancing* scheme. The circuit provides for its own internal sample-and-hold. On any reset, it automatically self-recalibrates itself. You can also force a recalibration at any time you care to.

For stereo audio operation, a left channel sample and a right channel sample are alternated using an input multiplexer. Each channel is sampled at 44 kilohertz for CD digital audio, or any sample rate from DC up to 50 kHz for special uses. The channel seperation and signal to noise ratio are both a respectable 92 decibels. Distortion is around 0.001 percent.

Your usual output is a serial data stream consisting of alternating 16-bit words of left and right channel data. While this is ideal for recording, it is rather fast and awkward for personal computer use. Very nicely, a serial to parallel converter is included that directly gives you the seperate left and right channel parallel 16-bit digital words at speeds that most personal computers can accept and use.

What you do is simply squirt in the left and right channel hi-fi audio, and the 16-bit digital words will fall off the other end of the board. It is that fast and that simple.

Since this is a more or less traditional converter circuit, you still need analog anti-alias filtering on your input. Figure four does show you a simple input driver and filter that should be good for test purposes. For your final circuit, though, a rather high quality anti-aliasing filter *must* be provided at each input.

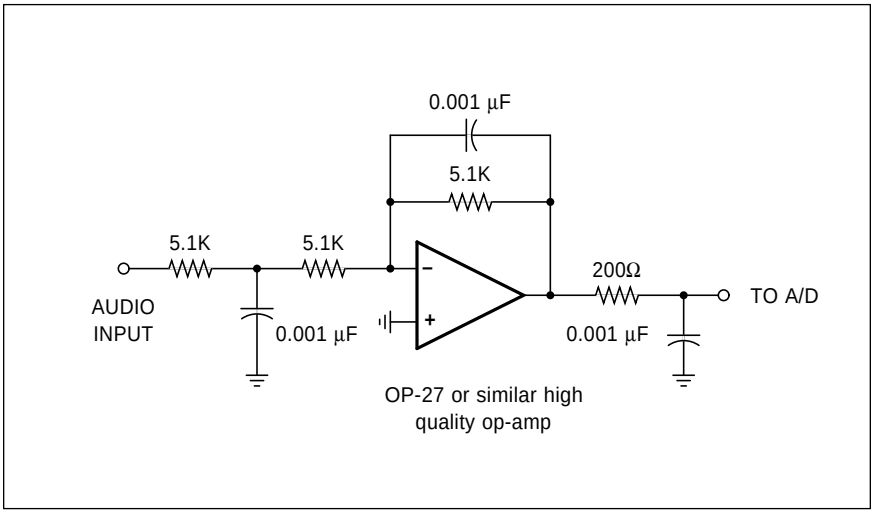


Fig. 4 – A RECOMMENDED INPUT DRIVER CIRCUIT. Additional anti-alias filtering is likely to be needed for your final CSZ5126 application.

Linear Technology is one unique source for all these single chip stereo CD audio anti-aliasing filters.

As a review, any A/D conversion scheme must limit its input frequencies to less than *one-half* of the clock frequency or quite serious aliasing will result. For a 44 kHz CD audio, a very high quality 22 kHz low pass filter must be provided.

There are all sorts of jumper and dipswitch options on the board for clocking sources, selecting the output codes, and such. Do be sure to carefully read all the ap-notes and data sheets before you use any of these units. Although these are essentially plug-and-go systems, a 25 Megahertz oscilloscope is absolutely essential for most of your initial testing and debugging. Do not even think of hacking these without having such a scope on hand.

One major gotcha on this evaluation board: Always apply your analog power before you apply your +5 volt digital power. Should digital power be applied without analog power, the chip can be destroyed. The simpliest way to handle all of this is to derive your digital +5 off of the analog +5 volt source. By the way, this A/D chip only draws a quarter of a watt, so it is usable for portable applications. There's also a standby mode.

Naturally, there is no reason you have to run this beast full tilt. Drop down to a 7 kHz sample rate, and you can handle voice grade audio, with far less memory storage needs inside of your personal computer.

Exciting as this chip and board combo sounds, the other two are even more impressive. Before we can understand them, though, we have to take a look at…

Oversampling and Delta-Sigma Conversion

It sure would be nice to do everything on a single chip. The CSZ5126 comes close, but it still needs a high performance anti-aliasing filter at its input for serious applications. And its specs are useful but not outstanding. Can we either get rid of this filter or substitute a simpler one?

Crystal reasoned that an entirely new approach to A/D conversion was needed. So, they went on back to the drawing board.

Well, the simplest A/D converter is a one bit converter. You can build up one of these by using nothing but a comparator or even an op-amp. And it turns out there is only one tiny thing wrong with a one bit A/D converter. And that is that the signal to quantizing noise ratio is a miserable seven decibels. Most people would instantly flush a one-bit converter as being uselessly noisy, especially for high quality services.

But wait. Crystal decided to ask just where all the quantization noise came from and just how all that noise was distributed. Well, it turns out that the quantization noise is pretty nearly white in nature, meaning that it is pretty near uniformly distributed from DC clear on up to your actual sampling frequency.

So what happens if we dramatically *raise* that sampling frequency? As figure five shows us, most of the noise ends up *outside* of the passband of your intended input frequencies. If you now *digitally* filter your output, you can literally throw away most of your quantization noise, and might ultimately get as much as 16 or even 20 bits of signal to noise ratio out of a one bit converter!

This newer process is known as *oversampling*, and one way of doing the one-bit A/D conversion is called *Delta-Sigma* conversion. One hairy but easily done process that greatly simplifies digital filtering is a digital signal processing scam called *decimation*, where high clock frequencies are progressively *folded over* back into lower and lower ones.

This is the route that Crystal chose to go on their newer chips. Besides being elegant, powerful, and cheap, the new method has another big plus – the sampling frequency is now so remote that your input anti-aliasing filter becomes utterly trivial. Even a single resistor and a capacitor can often do the job, and the input driver of figure four is more than adequate.

Crystal chose two different routes for their first delta-sigma A/D products. The first is the CS5501 and its companion CDB5501 evaluation board. This is a chip optomized for precision instrumentation measurement at sampling rates of 10 Hertz or less. Totally useless for audio, of course, but just what you need for precision electronic measurements. There's no point in updating digital displays faster than you can read them. And locking to a submultiple of the power line frequency might dramatically reduce hum, noise, and digit bobble.

A high performance anti-aliasing filter is included internally that lets you preselect your system bandwidth. The output is optomized for serial communications to a personal computer or over a modem. The linearity error is an absurdly low 0.0015 percent of full scale, or a little over one part in ten thousand.

And if that's not good enough for you, there's a 20 bit version in the works that should be able to handle such ultra-precise needs as an auto-counting weighing scale.

Their final chip boggles the mind. This is the CS5326 and its CDB5326 companion board. A full 16-bit delta-sigma oversampling stereo audio A/D processor with a 96 decibel signal to noise ratio, a passband ripple of 0.001 decibels, and a total harmonic distortion of 0.0015 percent. Plus only a trivial anti-aliasing filter is needed at the input to boot.

There's actually two seperate chips inside the package, one analog and one digital, since there's no way to get enough noise isolation on a single chip. The analog half still uses loose design rules and is continually being improved. Figure six shows you a simplified block diagram.

For our first contest this month, just tell me what you would do with a stereo audio front end or a precision analog instrumentation input circuit. There will be all the usual *Incredible Secret Money Machine* book prizes for the best dozen or so entries, with an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all.

As usual, send your entries directly to me per the *Need Help* box, and not to **Radio-Electronics** editorial.

We now have an astounding new set of power tools here. What are you going to do with them?

Sensors and Transducers

I sure do get a lot of helpline calls from **Radio-Electronics** readers after humidity sensors, strain gauges, pressure transducers, shaft encoders, and such. As with any other field, you start off with the trade journals and major supplier catalogs, and build up your personal data base from there.

That *Sensor and Transducer Re-*

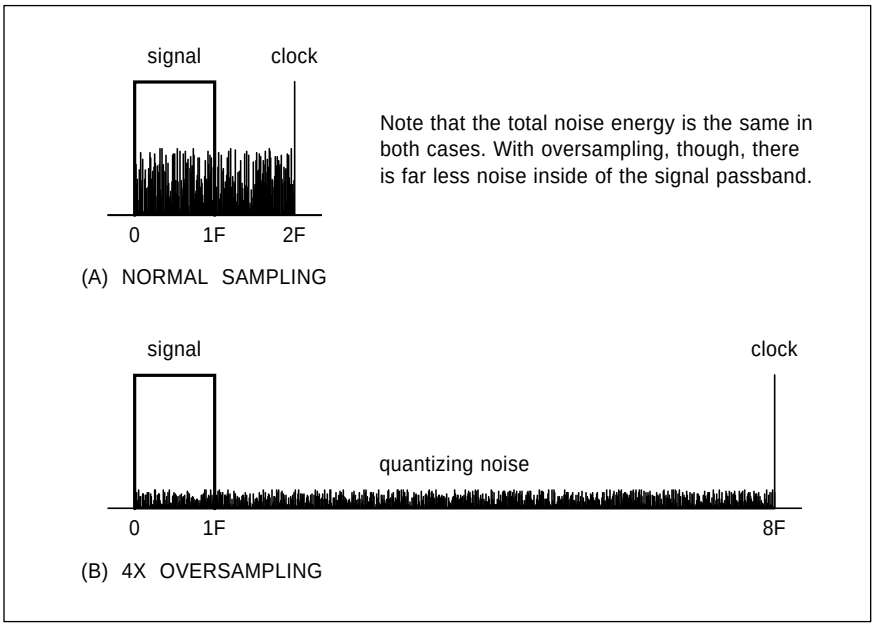


Fig. 5 – THE QUANTIZATION NOISE of an A/D converter is often distributed from DC on up to the sampling frequency. By oversampling and then digital low pass filtering, a 1-bit A/D converter can actually end up with far less noise than a 16-bit one! This is one of the key secrets to Crystal's Delta-Sigma conversion and post decimation digital filtering scheme.

SENSOR AND TRANSDUCER RESOURCES

Amperex
230 Duffy Avenue
Hicksville, NY 11802
(516) 931-6200

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

Nova Sensor
1055 Mission Court
Fremont, CA 94539
(415) 490-9100

SenSym
1255 Reamwood Avenue
Sunnyvale, CA 94089
(408) 744-1500

General Eastern
50 Hunt Street
Watertown, MA 02172
(617) 923-2386

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

Omega Engineering
Box 4047
Stamford, CT 06907
(203) 359-1660

Weathertronix
1165 National Drive
Sacramento, CA 95834
(800) 824-5873

IC Sensors
1701 McCarthy Blvd
Milpitas, CA 95035
(408) 432-1800

Motion Magazine
Box 6430
Orange, CA 92613
(714) 974-0200

Pollution Equip. News
8650 Babcock Blvd
Pittsburgh, PA 15237
(412) 364-5366

Yellow Springs Instrument
Box 279
Yellow Springs, OH 45387
(513) 767-7241

Intech
67 Alexander Drive
Research Tri, NC 27709
(919) 549-8411

Motorola
5005 E McDowell Road
Phoenix, AZ 85008
(602) 244-6900

Sensors
174 Concord Street
Peterborough, NH 03458
(603) 924-9631

sources sidebar shows you a few of my favorite information sources.
I guess I do like that free *Measurements and Control* trade journal best, with Carl Helmer's *Sensors* coming in a close second.

While it sounds a tad off-the-wall, *Pollution Equipment News* does have plenty of useful transducer and sensor info in it. I happened into this trade journal after I got rather tired of paying $2 per ounce for the hot tub clarifier that the sewage plant people were paying $2 a gallon for.

Omega Engineering probably has the widest selection of the sensors for pressure, temperature, humidity, ph, conductivity, strain, and whatever else available, along with lots of fine technical books, excellent ap-notes and ready-to-use instruments. Sadly, these folks are often very expensive.

Some very low cost temperature and pyroelectric people detector sensors are now avilable from *Amperex*, while the traditional source of very linear thermistor temperature sensors has been *Yellow Springs Instrument*.

While there still is no stable and wide ranging $5 humidity sensor yet available, two useful supply sources include *Omega* and *General Eastern*.

For pressure transducers, *Motorola* and *Micro Switch* were the traditional biggies, but they have now gotten totally eclipsed by the "gang of three", that include *SenSym*, *IC Sensors*, and *NovaSensor*. Start with SenSyms outstanding data book, slide rule, and ap note package.

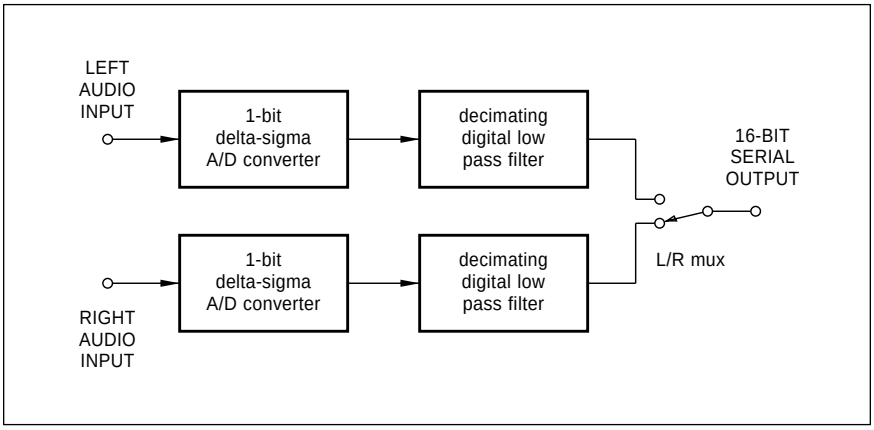


Fig. 7 – A SIMPLIFIED BLOCK DIAGRAM of the CSZ5326 A/D. The mind blowing specs here do include a 95 decibel dynamic range, 106 decibels of signal/noise ratio, 0.001 decibels of passband ripple, and a 0.0015 percent harmonic distortion for both 44 kHz stereo channels.

Shaft encoders and their low cost encoder conditioning integrated circuits are now readily available from *Hewlett-Packard*; others advertise in *Motion* magazine.

Be sure and let me know if you have any other favorites that belong on this list.

Discrete Soup Cans

All of the good folks at *SGS* have recently run a free "soup can" promotion. On your letterhead request, they will send you a can full of a dozen mainstream discrete semiconductors. And nearly every one of them is an outstanding hacker component that's easy and fun to use.

There's a zener diode, an ac power line controlling triac, a fast recovery diode, and a transient zapper. Fancier chips here include a medium power bipolar power transistor and a high power MOS transistor, a 5 volt regulator, and the obligatory 555 timer. From various logic families, you will find an octal latch, a hex inverter, a quad AND gate, and a dual AND-OR-INVERT gate.

This is an all around "must have" good deal. Let's start with the soup can and go a step further.

What are the *real* top forty hacker components? As a second contest this month, send me a list of a dozen or so of all of your favorite electronic parts, tell me why you like them, and why they do belong in the top forty. Later on, we'll work this up into a master list of all the good stuff. ✦

Don Lancaster's

Hardware Hacker

July, 1989

Toner reloading tools
More on digital audio
Getting an oscilloscope
Some bar code resources
Simple CMOS oscillators

There sure was quite a bit of interest in the digital audio front end we looked at last month. For those of you that missed it, *Crystal Semiconductor* has a few reasonably priced A/D converters and evaluation boards which can give you everything you will need to input full 16-bit stereo digital audio into your personal computer or other digital recording system. In short, a plug-and-go digital audio front end.

One possible recording device is a plain old SCSI hard disk drive. In fact, these are approaching a gigabyte in storage capability, which means that any old personal computer can record several hours of first rate CD quality stereo audio. This also means that the so-called "DAT controversy" is now totally moot, since there is now an installed user base of several tens of millions of computer systems that can, at least in theory, do a CD quality digital audiophile recording.

It should also be easy to adapt the digital audio front end to an ordinary VCR. This would make a very interesting construction project.

What about the playback? Getting from digital to analog isn't nearly the hassle as going the other way. One obvious route is to use any old CD player and intercept and override the bits halfway through. Otherwise, the needed D/A chips are readily available from *Analog Devices*, *Sony*, or from *Burr-Brown*.

Naturally, we've opened up some golden new opportunities here. All of the folks here at *Radio-Electronics* would be most interested in publishing some workable construction projects that you can come up with.

As usual, this is your column, and you can get technical help and off-the-wall networking per that *Need Help* box. Best calling times are 8-5 weekdays, *Mountain Standard Time*.

We seem to have a mixed bag this month…

Getting an Oscilloscope

I have long been a great fan of doing things on the cheap. The whole purpose of hacking is to get all the effects that you are after to show up reasonably well using the minimum possible time, cost, and effort. And I have seen countless projects ruined or changed into something entirely different and totally out of control by throwing far too much money at them far too soon.

On the other hand, there are one or two essential tools to any endeavor that are best done on a positively first rate and top notch basis.

As an obvious example, no photojournalist would ever try to operate without a camera. And their camera choice will almost always be a *Nikon*. *Instamatics* need not apply.

It amazes me how many hardware hackers are out there who do not own a personal oscillosope or have no reasonable access to one. This is not only absurd, but it is even a contradiction in terms. Very simply, you absolutely *must* own or have access to an oscilloscope if you are going to be at all serious about any hardware hacking. Most anything else can be faked – except a decent scope.

So which scope? In the past you scrimped and saved and maybe came up with a *Heathkit*, or a *B&K*. Or bought an old and ridiculously overweight and out of calibration surplus klunker. While, of course, dreaming of owning a real *Tektronix*.

But lately, the *Tektronix* folks have done so much so fast that it's no longer any contest. Not only are Tek scopes the very best on the market, they are also far and away the most cost effective and the most reliable. And, with falling weight, ridiculously improved performances and smaller sizes, the prices have also dropped.

For instance, outstanding hacker choices would be either their $695 model 2205 or their somewhat fancier model 2225. I personally own and use their much older 455, which cost me around four times as much as today's instruments, besides its being bulkier and heavier. All our beginning EAC electronics students use 2225 scopes and similar workstations. The stuff you didn't even dare to dream of back when I was a student.

Tektronix does have some freebies that make life easier for you. Check out their *Tek Direct* catalog, or any of their many free videotapes. They also have a good *ABC's of Oscilloscopes* experimenter book available. These are supposed to cost $3, but you can often talk them out of a free copy or two.

My Favorite Circuit

One recent hacker helpline caller needed a tunable 10 to 15 MegaHertz

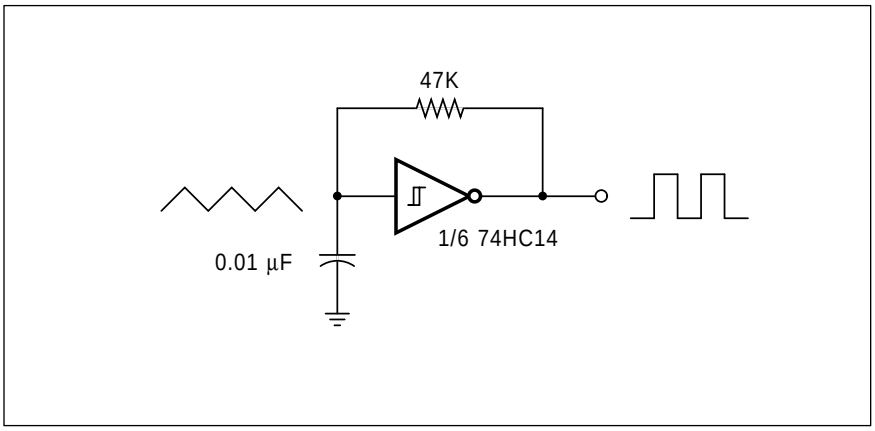


Fig. 1 – AN ELEGANTLY SIMPLE oscillator can be built using nothing but one resistor, a capacitor, and 1/6th of a CMOS hex Schmitt Trigger. Your output is a full supply square wave, while the input is a triangular wave that "saws" between the trigger's upper and lower trip points.

square wave generator. Preferably in the next ten minutes. I got to thinking about it for a while, and realized that a favorite circuit of mine could easily do the job. And then some.

I always have liked elegant simplicity – any stuff that can do more with less at lower cost. And I know of no better circuit than this one to use as an example.

Figure one shows you an oscillator that uses only 2-1/6 components. One resistor, a capacitor, and one-sixth of a hex CMOS Schmitt Trigger.

Let's review a bit here. A CMOS Schmitt Trigger is a digital logic device that will output a "1" when you input a "0" , and vice versa. If you are using the usual +5 volt supply, then the output "1" state will normally be +5 volts, and the output "0" state will normally be ground.

Now, if we used an ordinary inverter, any logic level above 2.5 volts would be considered a "1" and will drive the output low. And any logic level below 2.5 volts would be considered a "0" and thus would drive the output high. As this is a CMOS device, essentially zero input current is needed, so you can treat the input as an open circuit.

But, a Schmitt Trigger has a built-in snap-action or *hysteresis*. A *rising* input level has to exceed an *upper trip point*, typically around +3 volts, before the output will suddenly snap low. Similarly, any *falling* input level has to go below a *lower trip point*, usually around +2 volts, before your output will once again suddenly snap high. We can say the device has a one volt hysteresis or *dead band*. If you are sitting inside the dead band, you will not cause any output change unless you *exceed* your upper trip point or *go below* the lower one.

The intended use of CMOS Schmitt triggers is to clean up a sloppy, noisy or slowly changing input waveform. It is often a good idea to use these for most any real world input going into a hacker's circuit.

So how does our oscillator work? Let us assume we have just applied power. The charge on the capacitor cannot change instantaneously. Thus, there will be zero volts on your capacitor and the input will be held low, far below either trip point. The output of the inverter will now go high because of this low input.

The capacitor will slowly charge up through the resistor, following the usual R-C exponantial time constant rules. Eventually the voltage on the capacitor will exceed the upper trip point. This snaps the inverter output low, and the capacitor now will start discharging to the lower trip point.

When the lower trip point is finally reached, the output once again goes high, and the cycle will continuously repeat. Your capacitor will have a triangular waveform across it that range from two to three volts. Your inverter's output will be a sharp, full supply square wave whose frequency depends on the chosen resistor and capacitor values.

Because you are using CMOS, the oscillation frequency can be anything from hours to beyond 20 MegaHertz. Because of the open circuit input, there is virtually zero loading on the R-C network.

Two obvious chip choices are the hex 74HC14 or else the quad NAND 74HC132. Pinouts for these are shown you in figure two. The pricing should be around a quarter or so.

Some older and traditional CMOS devices that also work quite well here would include the 4093 and the 4584. These can be used with a nine volt battery or power supplies as high as 15 volts, while the '14 and the '132 are intended for use with supplies in the two to six volt range. Don't try to use HC devices above six volts or you will destroy them!

What can you do with all the other inverters or gates in the package? One obvious thing to do is take all five remaining inverters and put them in parallel for use as an output buffer. This isolates your RC timing from any changes in loading. Yes, you can even audibly power a speaker this way. No, it is not very loud. But it does give you an instant cable or continuity checker, a simple logic probe, or even a burgular alarm. The NAND chips can be *gated*, or turned on and off with an external signal. The rule is that a +5 volt input will *run* the oscillator, while a grounded input *stops* oscillation. Figure three shows you a gated alarm that bleeps at a selected rate.

Once again, you set the frequency with either your resistor or capacitor. Recommended resistor values range from 10K to 10 megohms for most of the lower frequencies. Its simpliest to experiment with component values to get the best sounding results or the most useful range.

Otherwise, you can calculate your charging current by using Ohm's law and the 2.5 volts that is the average across the resistor. There is a formula that says…

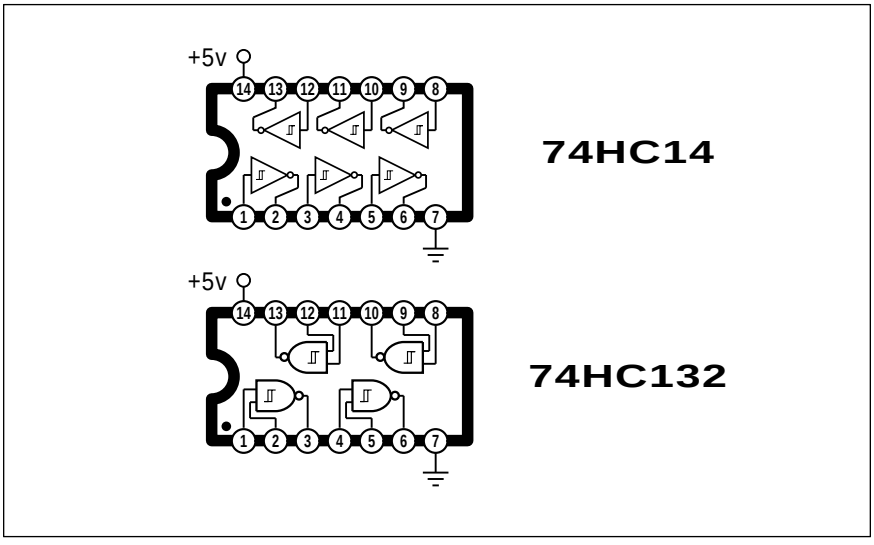


Fig. 2 – THE PINOUTS FOR THE TWO most popular CMOS Schmitt chips include both the hex inverting 74HC14 and the quad NAND 74HC132. While intended for +5 volt use, they will work over a +2 to +6 volt range. For higher voltages, use the older 4093 or 4584 devices instead. Note that both of the chips are shown top view.

$$C = i\Delta t/\Delta v$$

where C is the capacitance in picofarads, Δt is the half time period in microseconds, i is the charging current in microamps and Δv is 1 for the one volt triangular amplitude. The same formula will also work if C is in microfarads, i is in milliamps, and Δt is in milliseconds.

Naturally, this is a rather sloppy circuit for use where exact or precise frequencies are not required. Accuracies better than five percent will be hard to keep or hold. Even with the best of calculations, some trimming is likely to be needed.

Figure four shows you a crude but effective way to do a two-tone alarm for an emergency siren or a sound effect. There are two oscillators here. One runs slowly to set the duration of the low and high notes. The second runs fast to create the actual tones. That second timing capacitor will get switched into the circuit whenever the first oscillator is low and will get removed from the circuit when the first oscillator is high. The ratio of the two frequencies is set by the ratio of the two capacitors.

You can vary your resistance or switch your capacitors to change the frequency. Figure 5-A will show you how to add a pot to provide a 10:1 frequency range. If you use a linear pot here, your calibration will be very cramped to one end. Switching to a log pot will make things much worse. The trick is to use a log pot and put your calibration markings *on the pot dial* rather than on the panel. Sneaky, eh what?

In gated circuits, the first cycle after gating will usually be longer than the others, since the capacitor now has to charge all the way down from the positive supply, rather than from the upper trip point. A place where you can purposely use this effect might be in a keyboard autorepeat circuit.

Figure 5-B does show you how to adjust the duty cycle by using different resistors to charge and discharge the timing capacitor.

Tellyawhat. For our contest this month, just show me any variation at all on CMOS Schmitt Trigger oscillators. To keep things interesting this time around, you actually must build, verify, and test your circuit. There will be all of those usual *Incredible Secret Money Machine* book prizes for the best dozen or so entries, and an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two to the best entry of all.

As usual, send your entries directly to me per the *Need Help?* box, rather than to *Radio Electronics* editorial.

Toner Refilling Tools

In the past issues, as well as in all the *Hardware Hacker* reprints, we've seen how the *Canon* toner cartridges widely used in lots of popular laser printers and copiers can be reloaded many times. This can either be done as a rather profitable sideline service for others, or else to reduce your own per-page toner costs down into the jiffy printing range.

Since there's two brand new toner cartridge reloading tools available this month, I thought it might be a good time to review all of those top secret reloading tools and sources.

But first, the new stuff. A great SX cartridge pin puller is now available from *Thompson and Thompson* as their model *AXP43-007.09R Glompen-Stractor*. This one neatly and cleanly pulls the pins with zero damage. The older techniques used here included traverse cutting pliers, screw extractors, woodworking screw starters, or an obscure craftsman tool known as a #8 gimlet.

The really big news, though, is that it looks like SX drum hard recoating is now a reality. In theory, this could greatly extend that SX cartridge life and might eventually reduce or even eliminate the 15:1 per page toner cost penalty of the LaserJet II or either the LaserWriter NT or NTX.

One source of recoating drums and services is Arlin Shepard from *Lazer Products*. Their projected recoating costs are in the $8 range. It will be rather interesting to see how effective drum recoating becomes.

Let's go back to the old stuff. The best source for detailed maintenence and repair manuals on the CX and SX engines is *Hewlett Packard*. In fact, it is pretty near impossible to intelligently apply any Apple LaserWriter without owning the related HP manual that will cover it. The older CX engine (LaserJet, LaserWriter, LaserWriter Plus) manual is #02686-90904, while the newer SX engine (LaserJet II, LaserWriter NT and NTX) manual is part number #33440-90904.

HP has traditionally been a great source for the repair and replacement parts for all of the Apple machines, but lately they have been going to selling the major assemblies only. If the part you want is not individually available from HP, try *Custom Technology* or *Thompson and Thompson*.

As I've mentioned a time or two before, there are two reloading methods, the *punch and go* and the *total teardown*. I overwhelmingly prefer punch and go since it delivers far and away the lowest per-page toner costs to the end user. We charge $24 for local CX and SX reloads. I can still get away with such an outrageously

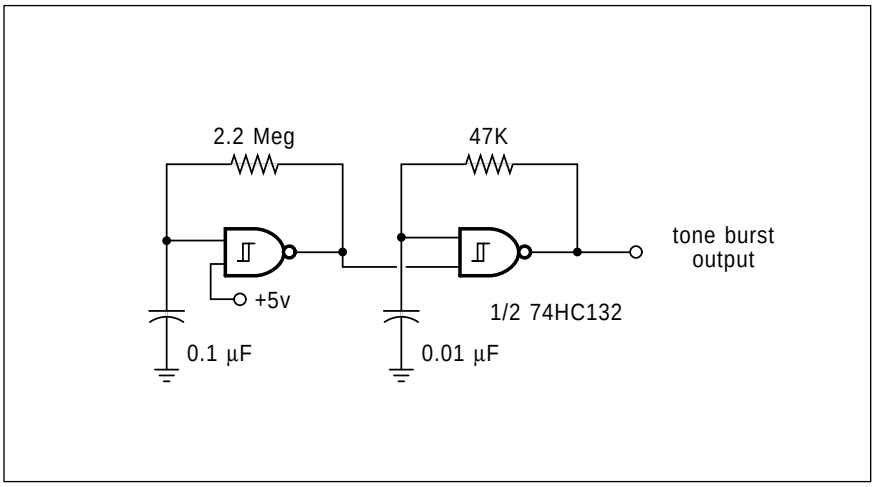


Fig. 3 – A GATED OSCILLATOR produces repeated tone bursts. The right RC values set the frequency, while the left ones determine the repeat rate.

high price since I do live in a rather remote rural area.

At any rate, if you do insist on a total teardown of a CX cartridge, the magic T-10 tamperproof *Torx* bit you will need is manufactured by *Evco* in their 945B700 set, and can be gotten through *Jensen Tools*.

For punch and go, the best way to produce smooth and truely round reloading and draining holes is to use a #3 *Unibit* from Vise Grip, or one of their imitators. These are once again available from *Jensen Tools* or most any of the large electrical contracting supply houses. One rather good way to replug the holes is with the tapered plastic closures from either *Caplugs* or *Niagara Plastics*.

Fusion roller wiper pads should be replaced each time you reload. One source of the custom manufactured peel-and-stick and silicon pressure lubricated Nomex felt strips is *Lazer Products*. These are normally included free with each bottle of their reload toner. A plain old 5/16 inch wood chisel is often the best way to remove the old wiper pad.

Note that washing and reusing a wiper pad is a no-no. Their purpose is to deliver a very precisely metered amount of silicon fusion oil. Improperly redone wiper pads might rather dramatically shorten the life of the expensive fuser assemblies.

A good drum lubricant is essential to a proper reload. You can get drum lubricant in bulk from those larger copier repair houses, while smaller quantities are available as *Pixie Dust*, once again from *Lazer Products*.

Several plastic strips are useful as well. A twelve mil thick piece of the clear butyrate plastic is useful as the feeler gauge for regapping cartridges that have heavy streaking problems. Similar plastic strips can be used for sealing the fresh toner in reloads that have to be shipped somewhere else or stored for long periods of time.

Do let me know if there are any favorite reloading tools of yours that I may have overlooked. Further details on all of this do appear in the *Hardware Hacker II* reprints.

Bar Code Resources

There's great heaping bunches of recent hacker interest in bar codes. So, in continuing our ongoing series of hacker resources, all of the needed insider info appears in our *Bar Code Resources* sidebar.

While there are lots of different bar codes today, far and away the most popular is called the *UPC Code*, and otherwise known as the *Uniform Product Code*. The full details and a complete set of standards is available from *The UPC Council*.

The leading bar code trade association is called the AIM, short for the *Association of Identification Manufacturers*. Among other things, they provide a free list of most major bar code sources and information.

There are around a dozen free bar code trade journals. Those that I am the most familiar with include *I.D. Systems*, *Automatic I.D. News*, and the *Identification Journal*.

One interesting resource is called *The Bar Code Information Service*. They supply a $4.95 *Bar Code Film Masters* book and a $19.95 *Technical Reference Guide*.

Generating your own bar codes by using the PostScript language along with your favorite word processor is trivial, and also turns out to be a very good initial project in PostScript programming. Surprising as it may sound, there just are not that many plug and go PostScript bar code font packages out there just yet, although dozens of low cost versions are almost certain to shortly appear. As of this writing, the only PostScript bar code product I do know about is an English one called *MacBarCoda*.

For more on PostScript in general, see my *Ask The Guru* sister column to this one that you will find over in *Computer Shopper*, or my *Ask the Guru* reprints.

New Tech Literature

Let us quickly review five of my favorite hacking resources. For "old line" or traditional military surplus electronics, its real hard to beat *Fair Radio Sales*. For a mind-boggling collection of nearly anything else in surplus, electronic and otherwise, *Jerryco* has to be the hands-down winner. For anything you can't find at your hardware store, along with the ability to cheaply custom cut up small pieces of metal or plastics, *Small Parts* is the only way to go.

For unusual publications, ranging the gamut from early machine shop techniques through antique radios all the way on down to perpetual motion machines and the free energy scams, check out *Lindsay Publications*. And for electronic bargains direct from electronic startups and other hackers, there's the great little *Nuts and Volts* shopper newsletter.

Texas Instruments has a new free *PAL Evaluation Kit*, which can even get you these sample programmable logic devices programmed for free. From *AT&T*, a thick new *Communication Devices* data book. And from *NEC Electronics*, the new *Memory Products* data book. This one does include full details on an improved definition television front end. It will

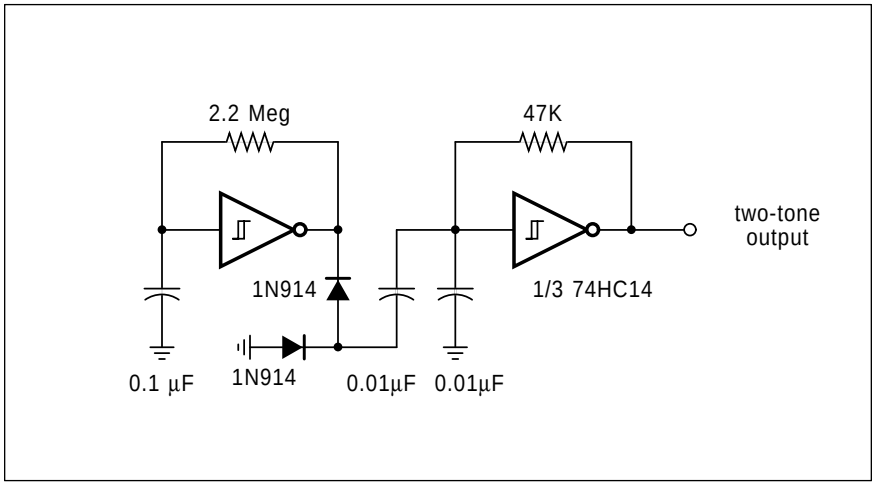


Fig. 4 – THIS TWO-TONE ALARM produces a distinctive "twee-dell" output. The spread between the high and low pitch is set by the ratio of the two right timing capacitors. Experiment to get the best-sounding results.

BAR CODE RESOURCES

A.I.M.
1326 Freeport Rd
Pittsburgh, PA 15238
(412) 963-8588

Automatic ID News
7500 Old Oak Blvd
Cleveland, OH 44130
(216) 243-8100

Bar Code Information Service
500 South Fourth St
Minneapolis, MN 55415
(800) 328-4960

ID Systems
174 Concord St
Peterborough, NH 03458
(603) 924-9631

Identification Journal
2640 N Halsted St
Chicago, IL 60614
(312) 528-6600

UPC Council
8163 Old Yankee Rd. #J
Dayton, OH 45458
(513) 435-3870

MacBarCoda
ComputaLabel Ltd
18a Regent St
Narborough, Leicester
England LE95DJ
011-44-533-750131

accept an ordinary NTSC (Never The Same Color) interlaced tv input and doubles the horizontal scan rate, to give you a flicker free and apparantly much sharper solid scan video output suitable for display on a Multi-Sync monitor or whatever.

One "must read" recent paper on *Levitation in Physics* appeared back in the January 20, 1989 *Science* that shows you proven methods to levitate both solids and liquids. Half a dozen viable methods are covered in depth with a good bibliography.

Newark Electronics has just come out with their free monster 1106 page *Catalog #110*. Although *Newark* was among the oldest of those "old line" distributors, they do stock everything in depth, have a tolerable minimum order, and are not nearly as hacker vicious as most of their competitors.

Some of the more interesting new surplus flyers this month do include *BCD Electro*, *All Electronics*, and *Time Line*. The latter has 256 element CCD line image video scanners for an unbelievable $5 each.

The old *Solid State Music* analog integrated circuits has been taken over by PMI. Ask for their *SSM Audio Products Catalog*. Included are voltage controlled amplifiers and filters, along with log/antilog circuits, low noise amplifiers, and lots of similar analog goodies.

You'll find a brand new free trade journal known as *Fiberoptic Product News*. Its chock full of infrared lasers and similar goodies. The free demo disks this month include *Precision Decisions* from *PMI*, and *UltiBoard PCB Design* from all of the people at *Ultimate Technology*.

There's lots of mechanical stuff this month. The *Vortec* people have all sorts of ultra-simple solid state cooling devices that use nothing but shop air to produce temperatures as low as -40 degrees Farenheit, or alternately produce significant amounts of localized cooling.

Value Plastics has free samples of their ultimate solution to low cost custom robotics pneumatic connectors – bondable fittings that can be mixed and matched most any way. Such things as custom manifolds are now utterly trivial to do.

And, *Merryweather Foam* now has a free sample card of their urethane and polyester foam products.

Stick II Products has a free sample flyer on many of their pressure sensitive foam tapes, while *Unette* has a free sample packet of their miniature liquid dispensing packages.

There's a rash of free samples on all of those new fifth generation op-amps floating around. Check out *Texas Instruments* for a freebie on their *Enhanced JFET* technology, or *National Semiconductor* for their *VIP Process* high speed op-amps and video buffer circuits.

Turning to my own products, yes, we are now shipping the *Hardware Hacker II* reprints of everything you have seen here in **Radio-Electronics**, along with my *Ask The Guru*, volumes I and II from the sister column to this one over in *Computer Shopper* magazine. And, yes, I do stock autographed copies of five of my classics – *TTL Cookbook*, *CMOS Cookbook*, *Active Filter Cookbook*, and *Micro Cookbook*, volumes I and II.

If you are at all into any *Apple* computing, you will find autographed copies of my *Enhancing Your Apple IIe*, volumes I & II, my *Apple Assembly Cookbook*, and my *AppleWriter Cookbook*, along with their companion disks available directly from me here at *Synergetics*.

And if you want to get further into PostScript, the magic language that does all of the artwork you see here using nothing but your favorite word processor, check into my *Intro To PostScript* video or my *PostScript Show and Tell* disks, now available for most personal computers.

As our usual reminder, this is your column, and you can gain tech help and off-the-wall networking per the number in the end box. Note that all of the names and numbers have been gathered together into a common file at the end of this reprint volume. All of those names and numbers in the resource sidebars have also gotten repeated a second time in our final *Names and Numbers* section.❖

Don Lancaster's

Hardware Hacker

August, 1989

Cold fusion secrets
Electrolytic chemistry
A new light show BBS
Future power resources
The isotopes of hydrogen

May you live in interesting times. This tome is being written in mid-April and the hacker helpline is now ringing off the hook.

Just in case you have been on a South Sea island or on a wilderness backpack these last few months, cold hydrogen fusion with net heat power generation has apparently been successfully demonstrated and has been verified in several chem labs around the world. Or so it seems.

And all of this got done through the chemist's equivalent of hardware hacking. That's science with a small "s", which involves a few dedicated individuals in limited labs, spending mostly their own personal money.

More to the point, the cold fusion appears to be emininetly hackable by just about anyone anywhere. Yes, it is rather dangerous, and yes, it gets fairly pricey for the needed materials. But if you quite carefully tune yourself into the key literature and then *thoroughly* study the work that everybody else is doing, and pay careful attention to several obvious safety rules, you can become a key player in what just may turn out to be far and away the most significant discovery of the twentieth century.

Let's see. The fun all began around April Fool's day 1989 when two pairs of competing chemists made several incredulous, yet apparently quite real claims. Stanley Pons of the University of Utah and Martin Fleishman of the University of Southhampton in England announced they had a cold fusion process that involved a simple electrolytic cell consisting of nothing but a platinum cathode, a palladium anode and some heavy water.

When a dc current was applied, the heavy water dissociated, the deuterium ions slowly moved into and got trapped by the palladium crystalline structure. Neutrons, tritium, and a rare isotope of helium were then detected, along with some net heat generation that seemed to exceed the electrical energy input by 4.5:1. All this at a heat energy density much greater than can easily be explained by any routine chemical reaction.

Meanwhile, Steven Jones over at Brigham Young University announced a remarkably similar series of experiments. These produced some apparent hydrogen fusion at a much slower rate without the excess energy generation.

Since it takes several weeks to get the reaction going, it did take a while to get confirmation. Early reports by independent teams that included Jay Bockris from Texas A&M University and others at Hungary University, the University of Arizona, and Moscow University did seem to confirm all of the initial reactions.

So, before you or I go any further on this at all, if you haven't already done so, drop what you are doing *immediately* and *run* on down to your local library or to *UMI* and get a copy of Steven Jones' paper appearing in *The Journal of Analytical Chemistry*, and a copy of Pons and Fleishmann's paper in *Nature*.

Since these papers will not appear until a week or two after my deadline for this month's column, you'll have to go fish for them. Look for a late April or May 1989 publication date. Otherwise, just check into your local library. You will find a large and fresh groove deeply worn in the floor in front of the copy machine. Just follow where that groove leads, and you'll be home free.

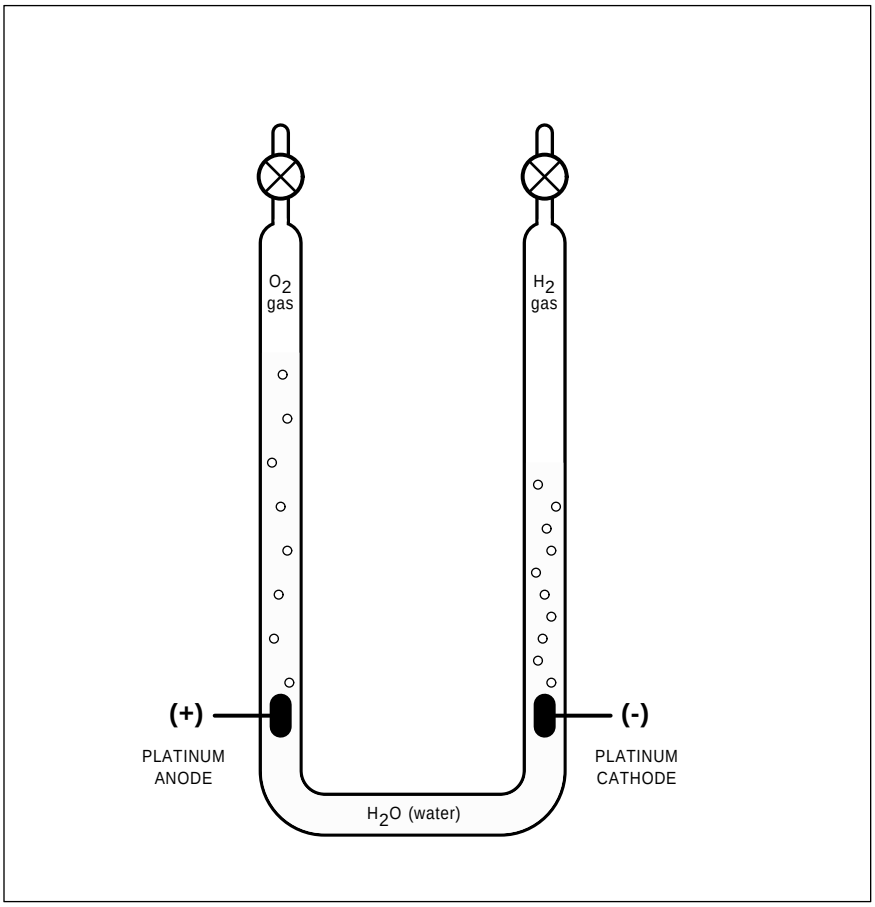


Fig. 1 – AN ELECTROLYTIC CELL is the key to the cold fusion experiments. This simple cell will break down or dissociate the water molecules into their hydrogen and oxygen atomic components.

What I thought I would do this month is try and give you some of the needed background information on fusion in general, cold fusion in particular, and on several of the resources you will need to get in on what could end up being the most exciting hacker opportunity of your lifetime…

Electrolytic Cells

Let's start off with the concept of an *electrolytic cell*, such as the one in figure one. The electrolytic cells are widely used today in such things as flashlight and storage batteries, for electoplating, in copper refining, for the corrosion protection of ships, and for electrochemistry in general.

The electrolytic cell will usually consist of a container that holds a liquid or semi-liquid *electrolyte*. Two electrical connections are made by way of a negative *cathode* and a positive *anode*. The choice of electrolyte and the anode and cathode materials depends on what you are trying to do with your electrolytic cell.

Let's assume the cell of figure one has a platinum anode and a platinum cathode, and that we fill it with plain old water. We'll add just a touch of acid to the water to make the solution more conductive.

Next, we will apply a dc current, negative to the cathode. We'll make this current large enough that the reaction goes on at a reasonable speed, but not so strong as to cause excess heating or other problems.

What happens is that the dc current causes several of the H_2O water molecules to break down or *dissociate* into positively charged hydrogen ions and negatively charged oxygen ions.

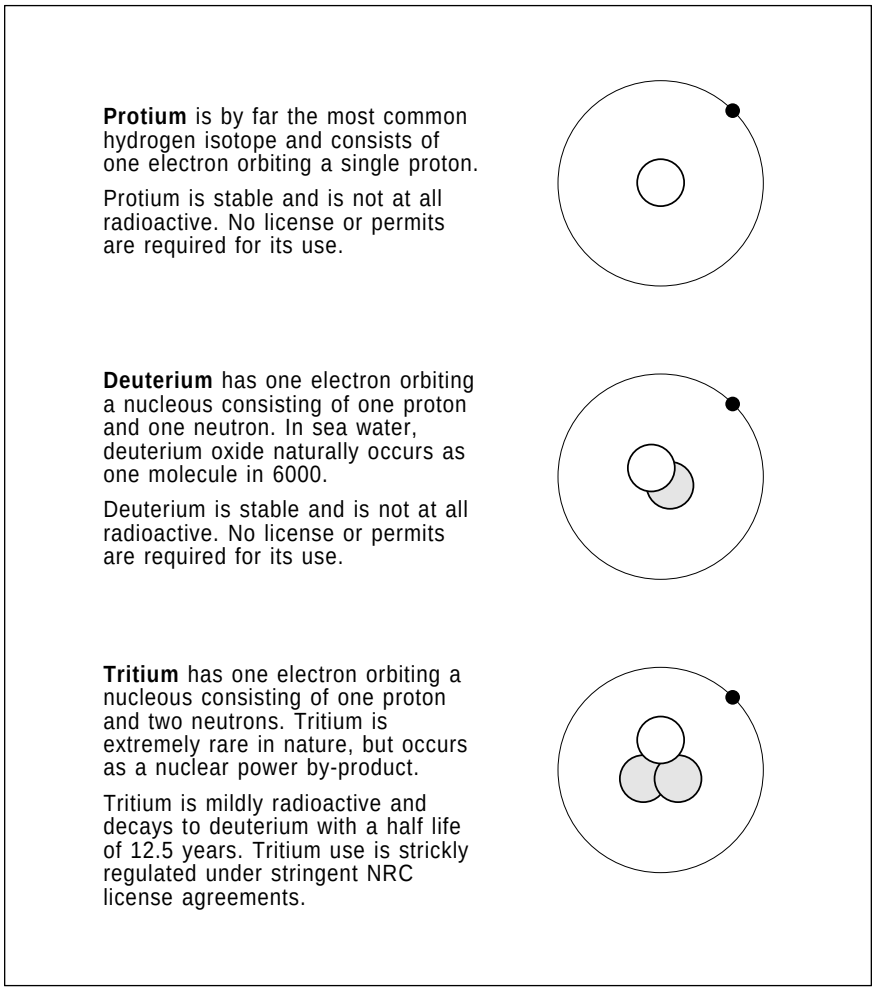


Fig. 2 – ISOTOPES are variations on an element that will have different atomic weights but largely identical chemical properties. The three isotopes of hydrogen are shown here. The Deuterium isotope gets used in the cold fusion experiments, initially in the form of deuterium oxide or "heavy water".

The positively charged hydrogen ions become attracted to the negative cathode. Since platinum is a noble metal that does not usually react with hydrogen, the hydrogen ions form bubbles at the cathode, combining to form diatomic H_2 hydrogen gas. The gas then floats upward, forming a gas pocket at the top of the right column.

Similarly, the negatively charged oxygen ions are attracted to the anode and will combine there to form a diatomic O_2 oxygen gas.

Let the reaction continue on long enough, and you'll end up with twice as much hydrogen as oxygen, thus verifying the chemical formula for water. The pure gases may then be extracted through the valves at the top of each column.

Much of the energy that was lost in the dissociation process is recoverable by burning the hydrogen in the recovered oxygen. This is called a *reversable* chemical reaction, and is often shown like this…

$$2H_2O + \text{energy} \leftrightarrow 2H_2 + O_2$$

We say this is a *reversable* reaction, in that you can either put energy in to convert water into hydrogen and oxygen, or else can burn hydrogen in oxygen to create water while we are liberating heat energy.

We will shortly see that the cold fusion reaction is basically an electrolytic cell. The electrolytic cell is also one way you can brew your own heavy water in your own bathroom, although there are cheaper and more modern processes available.

Uh, it seems that one of my many hats around here involves my being part of the Haz-Mat (Hazardous Materials) team on our fire department. So, let me tell you a thing or two about the dangers of hydrogen. Yeah, besides the *Hindenburg*. Obviously, hydrogen reacts very violently with oxygen to create water in the form of superheated steam. This can range from a rapid burning to a major explosion. The combustibility range of hydrogen is far greater than that of most other gases.

The tiniest, weakest spark of static electricity is all you need to set it off. Just to make things even more inter-

esting, hydrogen usually burns with a *totally invisible* flame, so you never know where the incredibly hot fire front is. In a haz-mat incident, a fireman will tie a rag onto the tip of his pike pole and use it, Knights-of-the-Round-Table jouster style, to find out where the edge of the fire is.

Isotopes

Now, that very term *isotope* may sound radioactive and dangerous and sneaky and illegal and scary, but an isotope is simply any variation on an atomic theme, much like a book can have either a red or a blue cover. An isotope is a variation on an atom that still retains identical chemical properties. Alike but different.

As figure two shows us, atoms in plain old hydrogen consist of a heavy positively charged *proton* that gets orbited by a light and a fast moving negatively charged *electron* satellite. A different name for this type of hydrogen is *proteum*. Proteum is far and away the most abundant form of hydrogen usually available.

There are lots of other particles that can go into any atom. One very common particle is called a *neutron* and can be thought of as a combined proton and electron having a zero net electrical charge and a mass slightly larger than a proton.

If you add one new neutron to the hydrogen neculus, you'll end up with an isotope of hydrogen that's known as *deuterium*. Deuterium is an isotope of hydrogen having one orbital negatively charged electron and a nuculeus consisting of one positively charged proton and one neutrally charged neutron. Deuterium is just as stable as ordinary hydrogen and is thus more or less permanant.

Add a second neutron to your nuculeous, and you pick up a hydrogen isotope known as *tritium*. This one is somewhat radioactive, in that tritium could emit beta particles (electrons) and decompose into deuterium with a half life of 12.5 years.

The most common form of hydrogen, of course, is in the molecules of ocean water. Ordinary water consists mostly of the proteum hydrogen isotopes. Around one water molecule in 6000 usually contains deuterium, and an extremely rare one might instead contain tritium.

These special deuterium molecules are called *heavy water*, and, as we've just seen, will usually occur in nature around one molecule in 6000. The chemical name for heavy water is *deuterium oxide*. The reason it gets called heavy water is obvious – it weighs nearly twice what the equal volume of ordinary water would.

Heavy water or deuterium oxide is *not* radioactive. It is just as stable as ordinary water. And, no, you don't need any sort of a license to make, buy, or use heavy water. It is even non-toxic, although its sheer weight might give you a stomach ache if you drank too much of it.

The important uses of heavy water include use as a moderator in a nuclear power plant, and as special *indicators* for chromatography, spectrum analysis, and radiography. Since the indicators have to be extremely pure, they can be quite expensive. Say $30 for a 50 milliliter flask.

You can easily make up your own heavy water, although not cheaply or quickly. Ordinary proteum hydrogen disassociates much faster than does deuterium hydrogen, so you simply run your electrolytic cell "still" from figure one, while continually pouring in fresh water. After a 100,000:1 reduction in the volume, any remaining water will end up as nearly pure deuterium oxide.

Today, though, most heavy water gets produced as a byproduct of the pollution control industry. Hydrogen sulfide is a nasty, odorous, and toxic gas that smells like rotten eggs.

When you react H_2S with water, a heavy water extraction can result. In fact, there is a total glut in the heavy water market today. If you aren't real fussy over the purity and buy it in large enough quantities, deuterium oxide costs only a dime a gallon.

So, at least one of our key ingredients of cold fusion is essentially free. And the other one, while expensive, appears to be totally reusable.

Fission and Fusion Reactions

What gets interesting fast is that you can convert matter into energy and vice versa. Einstein's $E=MC^2$ and all that good stuff.

In theory, there are two ways you can play the game. You can blast apart a big atom and split it up into smaller ones. This is called nuclear *fission*. The classic example of this is an atomic bomb.

As anyone from Chernoble might tell you, or anyone that owns WPPS

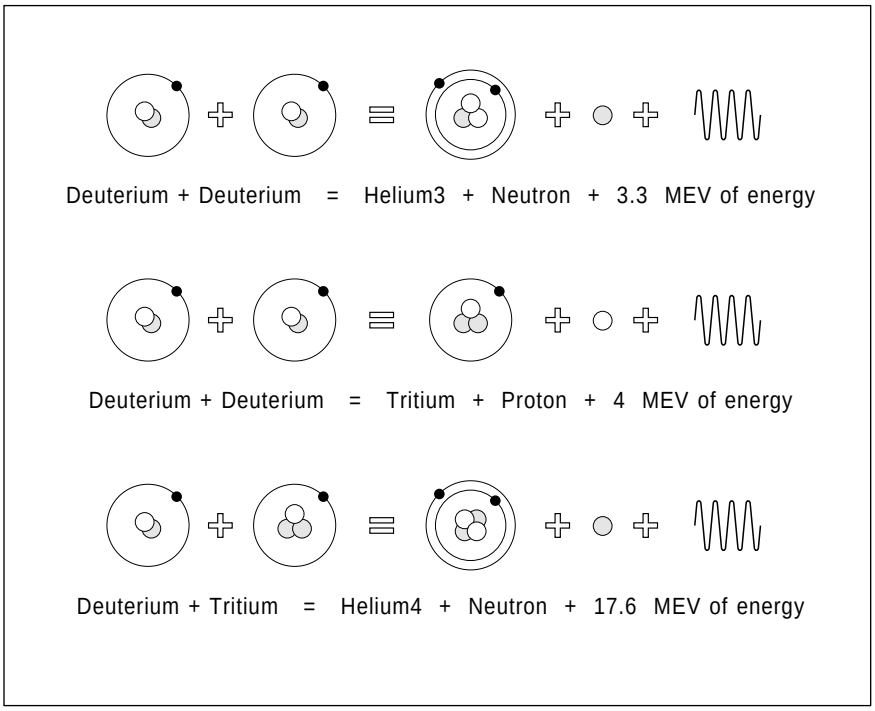


Fig. 3 – ATOMIC FUSION generates energy by combining smaller isotopes into larger ones. Here are three key fusion reactions.

bonds or any *Public Service of New Hampshire* common stock, nuclear fission energy sources simply do not work, owing to their incredible and monumental hidden societal costs. I personally feel that all of the nuclear power plant waste products in this country should be permanently stored in the reflecting pool at the Lincoln Memorial, as a fitting and long lasting tribute to both government folly and industrial greed.

By the way, there's a really great "sleeper" video rental known as *The Atomic Cafe*. Do watch it sometime. Great acting, only it isn't.

At any rate, you can also go the other way and take two small atoms and hold them together long enough for them to fuse together into one bigger atom. Which also can release great heaping bunches of net energy. This is called nuclear *fusion*, just like in a hydrogen bomb.

In theory, there is enough energy in the diluted deuterium atoms that are present in an ordinary teacup of water to exceed the energy of a tank of gasoline. And, also in theory, the fusion reactions should be very much more managable and have far fewer undesirable byproducts.

Naturally, there is no such thing as non-polluting energy, for the entropy of any energy release by itself leads to the ultimate and inescapable heat death of the planet.

And, just because something works in the lab does not mean that it can be made to generate enough excess power to pay both for itself and the interest on the money used to finance the project. And especially if all the non-obvious and hidden costs are fully taken into account.

For instance, if someone gave you all of the four percent efficient solar cells you wanted absolutely free, you still could *never* generate any useful amounts of sellable power with them, because the returned energy would never be able to pay for the land, the physical structure holding the cells, the associated electronics, and all the interest on the financing capital.

But, if used conservatively, efficiently and responsibly, a cold fusion process would appear, on the surface, to be somewhat comparable to solar as a potentially clean and low cost source of renewable energy.

More important to all us hackers, there doesn't seem to be any really compelling economics of scale that apply to cold fusion. The small and decentralized home power plants just might end up as viable as the big centralized ones. Possibly even vehicular generators for your car.

Three of the more interesting fusion reactions are shown to you in figure three. In the first two cases, you grab two deuterium ions and hold them together. In one possible reaction, you will obtain the isotope helium-3, a neutron, and 3.3 million electron volts of energy. Helium-3 is a stable, non-radioactive, and a very rare isotope of this inert gas. In a second possible reaction, you end up with tritium and 4 million electron volts of energy. At very high temperatures, these two fusion reactions are equally likely to happen.

You can also fuse a deuterium ion and a tritium ion together to create the plain old Helium-4 found in your nearest balloon, one neutron, and a whopping 17.6 million electron volts of energy.

The only tiny little catch is that all those deuterium ions don't like each other very much. In fact, they will violently repel each other if you try to get them within atomic distances of each other. Big science with a capital "S" has already blown zillions of gigabucks over several decades in a so far futile attempt to super-heat and super-energize deuterium ions so that they will fuse and then produce a net useful energy.

The Cold Fusion Cell

The reasoning behind cold fusion is very simple. Instead of raising the temperatures and energy levels of the deuterium ions to the point where enough of them will become energetic enough to collide with each other, you instead try to trap those deuterium ions inside of a crystal lattice. Putting them in jail, so to speak, so they can't run away. Like shooting fish in a barrel.

Palladium is a quite interesting candidate for cold fusion. Palladium can absorb as much as 900 times its own volume in deuterium atoms.

Palladium is a *transition metal* of atomic number 46. It is a metal that sees wide use for electronic contacts, dental alloys, and surgical tools.

The pre-announcement pricing of palladium was in the $150 per troy ounce area. It is up around $175 as of this writing, owing to speculation.

Figure four shows you the cold fusion cell as was used in the initial experiments. A platinum wire gets used as an anode and a palladium rod, typically 4 millimeters or so in diameter is used as the cathode. The cell gets filled with heavy water. A pinch of lithium hydroxide is added to improve the conductivity. The usual dc electrical current then gets applied to start the action.

This is an electrolytic cell, just like figure one. So, the oxygen ions go over to the platinum cathode and boil off. The deuterium ions then go to the palladium cathode and many will get trapped inside. After a few weeks of buildup, the new deuterium ions seem to end up clobbering all the old ones trapped in the structure, and will apparently begin cold fusion.

The observed effects include emitted neutrons, the detection of tritium, and the detection of that extremely rare helium-3 as would be expected in an ongoing fusion reaction.

More interestingly, heat energy is produced in several setups, typically raising the cathode temperature to the 176 degree Farenheit range.

Measurements of the output energy appear to exceed the electrical input used for the dissociation by a factor of 4.5. That energy density appears to be nearly ten times greater than what could be explained away by a normal chemical reaction.

But mysteries remain. There aren't nearly enough neutrons getting produced to justify the amount of heat that is generated. In fact, for the heat generated, the number of neutrons which should have gotten produced should have killed every one of the researchers outright. The apparent shortfall of neutrons is around one billion to one. Which misses by more than a country mile.

There are at least three possible explanations for the excess energy so far: (1) Those two deuterium fusion reactions may not be equally likely at room temperature, and that tritium product reaction is highly favored; (2) A new and a previously unknown atomic reaction is taking place; or (3)

Something really stupid (and totally useless) is really going on instead.

If I look into one of my Haz-Mat books, I'll find that palladium reacts violently with hydrogen and alcohol. So if a grad student spilled beer into one of those cells as a prank, it just might distort the results.

Nonetheless, the produced energy seems to far exceed any reasonable chemical reaction. Time will tell.

Getting Started

First, let's repeat some safety stuff. Hydrogen explodes. It does so very violently and sometimes invisibly. The cold fusion can produce neutrons in varying quantities that, if everything went wrong, could prove quite deadly. Dosimeters of one style or another should be essential. Random apparatus explosions have also been reported. One burned concrete.

You also just might want to skip mentioning to the local zoning folks that you are busy building miniature hydrogen bombs in your carport.

There is also the credibility factor. Make certain your experiment works several times and others have in fact reproduced it before you loudly proclaim it to the world.

Secondly, get both the key papers mentioned above. Then look into the sources and resources shown you in the *Cold Fusion Resources* sidebar. We've already seen how the *Journal of Analytical Chemistry* and *Nature* should contain the key horses mouth papers. They are certain to have lots of follow-up letters, experiments, and newer papers as well.

Two other important places to find ongoing information on cold fusion are *Science* for the technical details and *The Wall Street Journal* for any economic and business aspects.

One key library tool should be the *Science Citations Index*, which lets you take all the horses mouth names and then move them *forward* through time. Rest assured there'll be nothing useful published on cold fusion that does not mention Stanley Pons name at least a dozen times.

Two essential background texts are *The Handbook of Chemistry and Physics*, and the *Matter* volume from *The Life Science Library*. If you do not already own these two books as part of your personal library, you should not even be thinking about experimenting with cold fusion.

The sidebar also shows you all the usual places to go to get deuterium oxide, platinum wire, and palladium rods. Unfortunately, the heavy water sources I was able to dig up on such short notice are the quite expensive indicator-grade materials.

Above all, keep us informed on all your cold fusion progress. For once in a lifetime, the individual hardware hackers seem to have been given a more or less even playing field to run on. See that big "H" over there?

Exotic Metals and Rare Earths

The four palladium sources also stock just about any unusual metal or rare earth. Getting samples of exotic elements or compounds is no problem, so long as you are willing to pay exotic prices for them.

You might like to write the four sources shown to pick up their current catalogs and price lists.

Some examples: A sheet of gadolinium or hafnium costs $35. Indium wire costs $7 a gram, while Lanthanium Fluoride goes for $4 a gram.

Neodymium Oxide is a steal at 42 cents per gram. Scandium ingots are $88 each. Zirconium wire goes for $1.70 a gram, and so on.

One obvious caution: Before you try playing with *any* exotic element or chemical compound, be sure to *thoroughly* study its properties ahead of time, particularly the reactivity and toxicity. The good old *Handbook of Chemistry and Physics* is an obvious place to begin your research.

Your Own High Tech Venture

Well, if you ever want to try doing things the same way I do, check into my *Incredible Secret Money Machine* book that is chock full of ideas for your own technical or craft venture. I just happen to have several autographed copies on hand here that I'll be happy to lay on you.

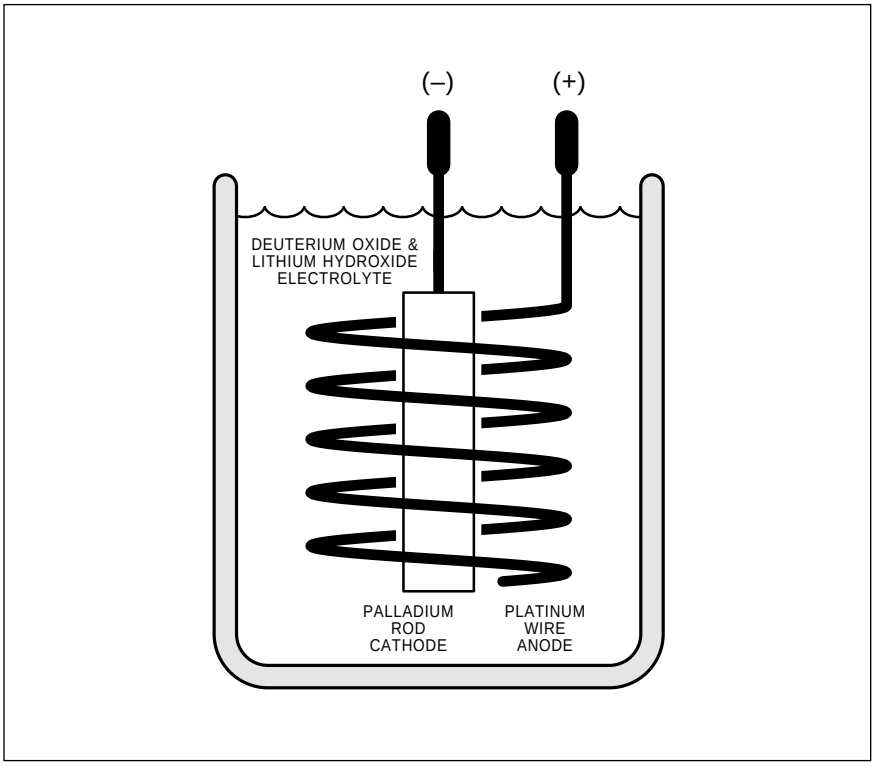


Fig. 4 – COLD FUSION appears to get produced in this experimental electrolytic cell. The heavy water dissociates into deuterium and oxygen ions. The deuterium ions will migrate to the palladium cathode where many of them become trapped in its crystalline structure. Some of the later arriving deuterium ions apparently cold fuse with the trapped ones, apparently producing both heat and at least a few of the expected fusion by-products. But it is far too soon to tell for sure.

COLD FUSION RESOURCES

Information Sources...

Analytical Chemistry/ACS
1155 16th Street NW
Washington, DC 20036
(202) 872-4570

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

Dialog
3460 Hillview Avenue
Palo Alto, Ca 94304
(415) 858-2700

UMI
300 North Zeeb Road
Ann Arbor, MI 48106
(800) 521-3044

Nature
65 Bleecker Street
New York City, NY 10012
(212) 477-9600

Wall Street Journal
420 Lexington Ave
New York City NY 10170
(212) 808-6960

Palladium and Platinum...

Aesar
PO Box 1087
Seabrook, NH 03874
(800) 343-1990

ESPI
5310 Derry
Agouro, CA 91301
(800) 638-2581

Cerac
PO Box 1178
Milwaukee, WI 53201
(414) 289-9800

Goodfellow
301 Lindenwood Dr, Ste 1
Malvern, PA 19355
(800) 821-2870

Deuterium Oxide...

Alpha Products
152 Andover Street
Danvers, MA 01923
(800) 343-0660

ICN Biochemicals Inc.
3300 Hyland Avenue
Costa Mesa, CA 92626
(714) 545-0113

Canadian AEC
344 Slater Street
Ontario, ONT K1A-0S4
(613) 237-3270

Isotech Inc.
3858 Benner Road
Miamisburg, OH 45342
(800) 448-9760

New Tech Literature

Meredith Instruments has a new hacker catalog out. Their laser tubes start at $35, and they have a new light show BBS on line at (602) 867-7258.

Two other surplus catalogs that did come in today's mail included *BNF Enterprises* for cheap audio, optics, and electronics; plus *C&H Sales* for raw iron steppers, motors, hydraulics, valves, and optical assemblies.

Two new free trade journals this month are *Advanced Imaging* on high end video systems and support, along with the *SMT Nutshell News* on surface mount technology.

Since we seem to be doing things by twos here, this month's data books include that new *Communications Products* data book from *Thomson Components* on modems, telephone chips, digital signal processing, and A/D converters; and the *CMOS Programmable Logic Data Book* from the *Samsung* folks.

Two additional sources for photochemical machining include *Buckbee Mears* and *Microphoto Inc.*

Sprague has a new data sheet on their ULN3800A FMX stereo decoder, intended for all those new extended range broadcast stereo FM services. *National* has a pair of interesting data sheets out, one on their LM1951 high side driver, and one on their LM12C op amp with a 150 watt rating.

Siliconix has a pair of switching field effect transistor samples that are absolutely ideal hacker parts. The samples are free in singles when you phone or write for them using the usual letterhead request.

The first is the *2N7000 Fetlington*. This is a small package field effect transistor that is rated 60 volts and up to 200 milliamperes of continuous current. In quantity, this beauty sells for less than a dime. It is ideal for such things as driving relays, small solenoid valves, alarms, incadescent lamps, and such.

Their second sample is the *2N7004 FETDIP*. This is a slightly larger device with a much higher power rating. It can handle 100 volts and up to six watts of continuous power dissipation with suitable heatsinking. Maxiumum current is one ampere. The on resistance is a low 0.6 ohms. Uses would include line drivers, high power switches, current sinks, and most anywhere else you needed to switch a medium power load.

Several test circuits are included on each of the sample cards. Higher voltage versions are also available, up to the 2N7006 that is rated to 350 volts. Since negligible input current is needed, these are well suited for microprocessor control of a medium power load.

A *MS-111* stripping agent which could dissolve epoxy and urethane encapsulants is obtainable through *Miller-Stephenson*; they also provide free samples on their wide line of electronic chemicals.

Turning to my own products, my classic *Active Filter Cookbook* has somehow gotten up to its fourteenth printing. I now have autographed copies in stock for you here at *Synergetics*. I have also completely redone my *Introduction to PostScript* VHS video. It now includes details on toner cartridge reloading, the *Kroy Kolor* process, desktop publishing resources, and new binding systems. All the figures you see in this column were created full camera-ready by using nothing but PostScript and an ordinary word processor. PostScript is the key secret to tabletop book-on-demand publishing.

As per usual, this is your column and you can get technical help or off-the-wall networking per the *Need Help?* box.✦

Don Lancaster's

Hardware Hacker

September, 1989

More on cold fusion
Mystery chip solved!
Cheap digital compass
Book-on-demand ideas
Humidity measurement

Well, a month has passed. For me, this is still late May. Incredibly, the cold fusion has neither been fully proven nor disproven. Here's how things stand at this writing:

Very low level and *muon catalyzed* fusion effects have now been demonstrated at room temperature, pretty much to everyone's satisfaction.

Among other tests, some cells are producing a tritium fusion byproduct that is nearly a thousand times above the expected background levels.

While apparently useless for power production, these low level studies do point towards solving some sticky geochronology problems and have opened up major thinking about new directions for fusion research.

Separately a few labs, (somewhere between 4 and 35, depending on who is counting and who is talking) have demonstrated a very substantial heat generation in test setups which far exceed their electrical energy input and which appear to be way in excess of what you would expect from any reasonable or easily explained chemical reaction. To date, the argument that high level cold fusion is taking place is based on a "what else could it possibly be?" theory.

Apparently, the metallurgy of the palladium anodes is very critical, and there is some other black magic involved which certain reasearchers do refuse to talk about. At least so far.

The big reason for worrying about whether the excess heat production is really cold fusion or not is that any chemical reaction would require an earlier energy input.

All cold fusion would require is nickel-a-gallon heavy water. Thus, *if* the reaction is physical, chemical, or simply a subtle form of a catalyzed hydrogen explosion, we will probably end up with an improved yuppie ski boot heater or a possible new direction for battery research.

Instead, *if* the reaction is in fact a cold fusion one, then we now have the development of the century, if not the millenium.

So what's a hacker to do? First and foremost, *get and keep informed!* The best places to do this are in the *News and Comments* section from *Science* magazine, in the *Technology* columns (usually on page B-4) of your *Wall Street Journal*, and the many on-line resources of the *Daialog Information Service* at your library.

What you want to watch out for is something someplace that says "Do exactly this exactly this way, and the odds will be very high that you will get excess heat production." Then go for it. But till then, there is no sense in buying palladium rods that end up with the wrong metallurgy or involve other fundamental problems.

I will let you know where to look, just as soon as I find out myself.

Meanwhile, there appears to be nothing but bad news from the high temperature superconductor research these days. It seems that there are some very fundamental (and possibly insurmountable) reasons why all the known types of the high temperature superconductors appear to be unable to *ever* support the extreme current densities needed to levitate trains or

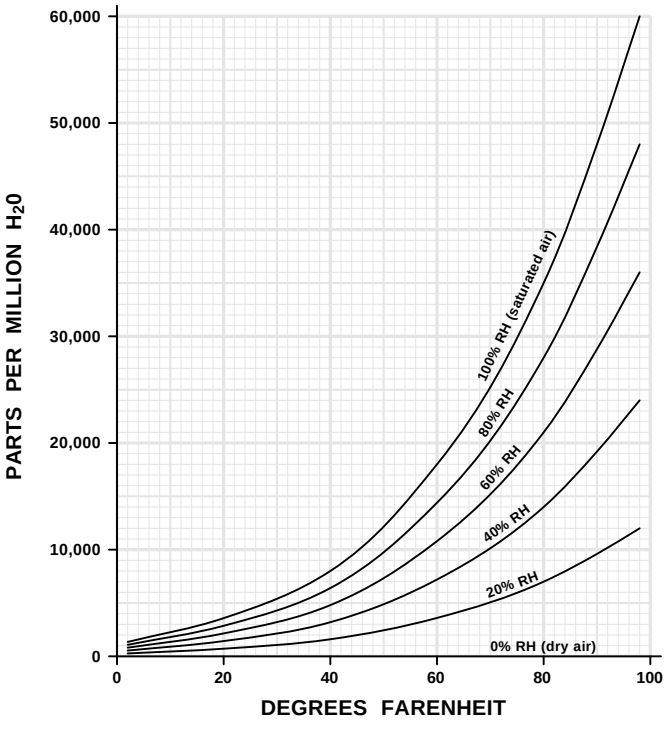


Fig. 1 – THE ALLOWABLE AMOUNT OF WATER VAPOR in air is a very strong function of temperature. Absolute humidity is a direct measure of that amount, expressed in parts per million or similar units. Relative humidity is instead a percentage ratio of how much moisture really is present compared against the maximum allowed for the current temperature.

make commercial power distrubition more efficient.

Again, do see *Science* magazine for the ongoing bad news.

For some good news, we have a *tinaja quest* winner from our phase plane contest. And he has some great new free stuff for you, namely an IBM Pascal program that directly can generate full color or hard copy Lorenz attractor "owl's mask" chaotic trademarks for you. Just send a disk and a postpaid return package to Toni Patti of the *Cryptosystems Journal* for your free copy. If you can afford to, throw in an engraved portrait or two of Abe Lincoln for his trouble.

Our big feature for this month does involve several new humidity sensor products. But first…

Mystery Chip Solved!

Every once in a while, some new chip comes along that *every* hacker wants to glomp onto, in one way or another. So much so that I've been getting over a dozen calls a day on this one. This dude is a stereo FM modulator chip, intended to wirelessly couple a CD player to a FM car radio. And do so with top quality.

Now, the normal way you find out about new hacker chips is through all of those electronics trade journals. Especially *E.E. Times*, *Electronics*, *EDN*, *Electronic News Electronic Design*, *Electronic Products*, and the *Electronic Component News*. As per usual, you get addresses on these and the 55,000 other trade journals (many free to qualified subscribers) through *Uhlricht's Periodicals Dictionary* on the reference shelf at your library.

A second way of getting at chips is by going to those low cost *ECG* and NTE directories. These are great for leafing through backwards on a chip pinout-by-pinout basis to get at the good stuff. And they do sell single quantities of most listed chips on a no-hassle basis.

This particular chip hasn't made it yet to the trade journals. The CD to FM converter is a *Rohm* part number BA-1404, and is available through *Jay Ohm Electronics*. Cost is around $1.50 each in lots of twenty.

Ready-to-go kits are also listed in several classified ad sources here in *Radio-Electronics* and in the *Nuts and Volts* shopper.

I don't have my samples yet, so we'll hold off on full details for a column or two. But for the first of our two contests this month, just tell me what you would do with a cheap, low power, and a high quality stereo FM broadcaster chip.

There'll be all the usual *Incredible Secret Money Machine* books for the better entries, along with an all expense paid (FOB Thatcher, AZ) *tinaja quest* going to the very best of all.

Be sure to send all of your entries directly to me per that *Need Help?* box, and *not* to the *Radio Electronics* editorial offices.

Book-on-Demand Publishing Opportunities

Those of you that are following my sister column to this one over in the *Computer Shopper* magazine know that I am into doing book-on-demand publishing in a very big way.

Very simply, you can now produce books on any subject while using nothing but a PostScript laser printer on your kitchen table, and do so fully professionally, and at the costs and quality levels that today can match and often surpass jiffy printing.

You can now literally beat your own book out on a brick in the back yard and have it turn out as good as commercial publishing.

Among the many overwhelming advantages of the book-on-demand printing are that the author can be paid as much as a 50 percent royalty of your final selling price; that the production time gets measured in minutes rather than months; that no monumental (and non-refundable!) front end costs are involved since you only print the books you need at any given time; that the customer's name can be custom printed in gold on the cover; that your back list can continue forever without any inventory tax and similar IRS penalties; that review and promotional copies are available twenty minutes after the author submits his manuscript; and that changes, revisions, or updates can be made at any time.

If we were to sum up four years of research and countless *Ask the Guru* columns into five book-on-demand rules, they would look like this (1) use only a later version PostScript speaking laser printer; (2) use a local hard disk directly attached to your

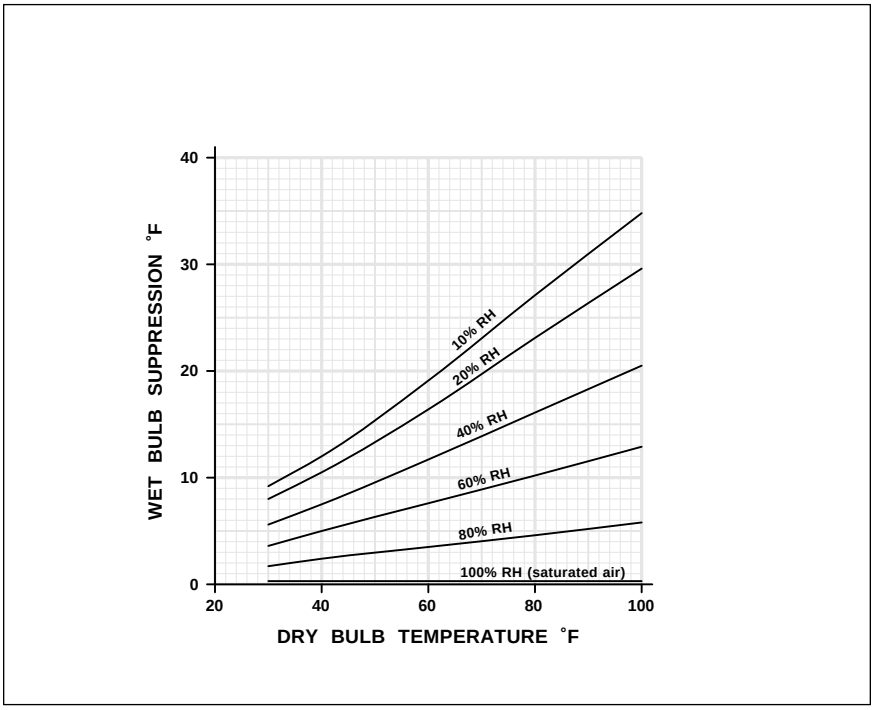


Fig. 2 – WEATHER FORECASTERS OFTEN will use a wet-bulb, dry-bulb sling psychrometer to measure the relative humidity. The lower the humidity, the more the evaporative cooling of the wet bulb, and the lower its temperature. This graph calculates the relative humidity for you.

printer; (3) do all your own cartridge refilling to get your toner costs under 0.33 cents per page; (4) use duplex (two sided) printing if possible; and (5) compile your PostScript run time code to eliminate or minimize page makeready times.

So what does all this have to do with our hardware hacking? Just this – the new or used printing machinery is outrageously expensive and most used printing equipment salesmen are totally useless and incredibly arrogant epsilon minuses. There is a whole new world of laser printing out there that needs brand new and ultra low cost designs of *small scale* press and bindery systems.

For instance, in previous columns we've seen a low cost subsititute for the grossly overpriced *Kroy* and *Omnicrom* fusion machines. And I am currently working up a new method to convert a $25 sander into a paper jogger.

The stuff we really need, though, is a clamping gullitone paper cutter that costs the end user less than $99; cheap folders and padders; low cost home binding systems that could use any cover materials and can support spline printing; paper drills; sane color proofing technology; home foil hot stamping systems; slitters and perforators; cheaper "print on anything" pad printers; new die cutting methods; laser compatible thermography solutions; etc. etc.

To get an idea of what is needed, pick up a free copy of *The Printer's Shopper* and open it to nearly any page. Then figure out how to reduce all the prices by not less than 5:1.

I suspect your ultimate approach would be build-your-own kits of only the essential parts needed for any of these. And all you hardware hackers have the inside track on this sort of thing. Go for it.

So, as a second contest this month, just show me any ultra-cheap way to slash the end user cost of any printing or production equipment that is suitable for use with home book-on-demand publishing.

Let's have your input on this. Its a hot topic with unlimited potential.

Fundamentals of Humidity

The price of hacker humidity sensors is at long last dropping down into the $5 range, so I thought we might review just what humidity is and how we might sense it.

The humidity is simply how much water vapor is present in the air at any particular time. This gets very important for weather forecasting, air conditioning, environmental monitoring, process controls, home comfort, cave studies, in energy management, and can become postively crucial in wildland fire fighting.

Air consists of a mixture of many gases which is mostly 4/5ths nitrogen and 1/5th oxygen. Since water vapor is also a gas, it can form a mixture with the other gases in air, following a chemical *law of partial pressures*. The maximum amount of water vapor possible in the air will vary with the exact air composition and the atmospheric pressure. It also changes very strongly with temperature.

One way to measure the amount of water in air is in *parts per million*. At zero degrees Farenheit, the maximum amount of allowable water vapor in the air is around 1200 parts per million; at 100 degrees Farenheit, your maximum allowable amount of water vapor is something like 63,000 parts per million.

This temperature relationship is very non-linear. Rule number one of humidity sensing is that humidity is a very strong and a highly non-linear function of temperature; you *always* have to measure and specify your temperature at the same time you make your humidity measurement.

There are two ways of specifying humidity, as *absolute* and *relative*. The absolute humidity is how much water vapor that really is present at a given temperature, and is expressed in parts per million, grains per pound, or in some similar way. The relative humidity is the percentage of water vapor that's present as a ratio of the maximum allowable for the current temperature.

Figure one shows the relationship between these two. Air that holds all of the water vapor it possibly can at some temperature is said to have been *saturated*. Try to add any more water vapor to the air and it will rain on you or else turn to fog. Air that holds no water vapor at all is said to be *dry* air.

Totally saturated air has a relative humidity of 100 percent. Totally dry air has a relative humidity of 0 percent. Air that holds half the allowable moisture has a relative humidity of 50 percent.

Cool air can not retain as much water vapor as warm air can. Thus, as

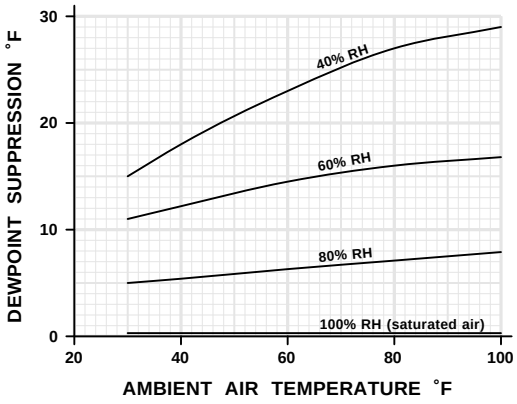


Fig. 3 – PRECISION LABORATORY MEASUREMENT of relative humidity is done by chilling the air to its dewpoint to find the equivalent air temperature for full saturation. Usually a servo driven mirror will fog or frost at the dewpoint, altering a sensing beam of light. Dewpoint measurements are best used at the higher humidity and temperature ranges.

you lower the temperature, you often will raise your humidity, and vice versa. In particular, cooling air conditioners have to condense out some water as the temperature is lowered.

There is often a *condensate pump* or a *condensate line* in air conditioners to dispose of the "rain" that results as you cool the air. In some parts of the country, the evaporative coolers, or "swamp boxes" purposely will inject water into your air. This evaporation lowers the temperature and raises the humidity.

Unfortunately, evaporative coolers are only real useful in the driest of climates. They can get unbearably muggy elsewhere.

Humidity Sensors

As you just might guess, there are many different methods of measuring both absolute and relative humidity. These depend on the accuracy you need, and each method will work best over some specified range of temperatures and relative humidities.

The *Humidity Resources* sidebar shows you some of the many places to go to get info on humidity sensors and sensing systems.

The simplest humidity sensor is a long, unwashed blond hair. This is an example of a *hygroscopic* material that will get longer or shorter as it absorbs or releases the water vapor. Some nylon cords are also moisture sensitive. For years, there have been *Honeywell* humidity sensors based on a nylon strip that have been kicking around the surplus market. One $1.95 source for these is *Fair Radio Sales* as stock #H46B1150.

Dial type analog humidity displays are available from *Abbeon-CAL*, or *Heathkit*, or *Edmund Scientific*.

The traditional weather forecasting way of measuring relative humidity is with a *sling psychrometer*. With a psychrometer, you have two thermometers. One gets kept dry, while the other is kept wet with a moisturizing wick. What you have in essence is a miniature evaporative cooler. The wet bulb temperature will suppress as the evaporating water cools it. The amount of suppression can be related to your humidity simply by following the curve of figure two.

In practice, the wet-bulb, dry-bulb setups do not perform all that accurately, owing to water contamination and deposit buildups.

The traditional laboratory method of measuring relative humidity is by lowering your temperature until it rains or fogs, and then measuring this *dewpoint* temperature where the air becomes fully saturated.

In many instruments, a *chilled mirror* will get thermoelectrically cooled. A light beam bounces off the mirror. If the mirror is not fogged, the light beam reaches a photosensor. If the mirror fogs at the dewpoint, the light beam diffuses and causes a different reading. Normally a servo system is used to continuously track the dew- point over time.

The dewpoint is different from and lower than the wet bulb temperature. This happens because of the highly non-linear relation between the temperature and humidity. Figure three shows you the relationship between dewpoint and relative humidity.

In general dewpoint instruments are quite accurate and quite costly. They also will work across the full range of relative humidities and are one of the few methods which can accurately measure extremely high humidity values.

There are a number of electronic humidity sensors. The price on these are finally dropping to a point where they are of hacker interest.

For instance, *Phys-Chem Scientific* has a line of humidity sensors that are based on the surface resistivity of a custom polymer. Their resistance changes as a non-linear function of relative humidity. Surface sensors of this type tend to be fast but sensitive to contamination.

The *Panametrics* people have a line of *Minicap* humidity sensors that do in fact drop down to $5 per unit in large quantities. These sensors are essentially a capacitor whose dielectric is humidity sensitive. Unlike the surface sensing units we just looked at, the sensing takes place throughout all the volume of the material. This sensor works best at medium relative humidity values. While less sensitive to contamination, the response time can also be longer.

Since this sensor is basically a capacitor, it lends itself very well to low power sensing. The CMOS 555 timer can be used with it to convert relative humidity to frequency.

The big news this month, though, is that there is a brand new, accurate, and cheap way of measuring absolute humidity that can completely bypass all the problems of all the relative humidity methods we've just looked at. A typical example is the HS-5 sensor from *Shibaura*, which is distributed by *Mitsubishi*. Figure four shows us this sensor.

This uses a sneaky and an indirect way of measuring the humidity. The thermal conductivity of the air varies with humidity, being lowest with dry air and highest at the high humidity values. This is one reason why dry air is generally far more comfortable than humid air.

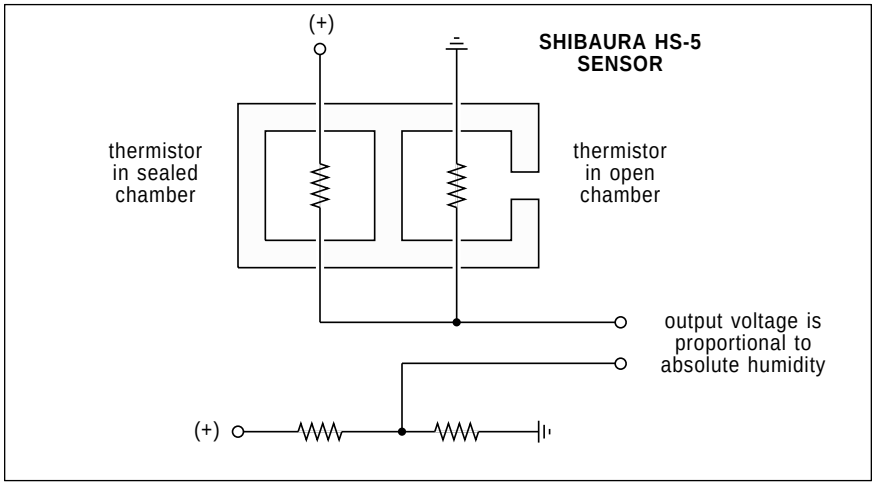


Fig. 4 – THIS NEW ABSOLUTE HUMIDITY SENSOR from Shibaura uses the difference in the thermal conductivity between dry and humid air to produce an output voltage. Both thermistors are run in their self-heating range.

A pair of thermistor sensors gets used. One is hermetically sealed into a container holding extremely dry air. The other lies inside a similar container that has access to the ambient air. Since both containers are in contact with each other, they should remain at the same temperature.

Currents are then applied to both thermistors in a bridge arrangement. Both thermistors are run up into their non-linear self-heating range. The dry sensor will lose very little heat through thermal conductivity. The wet sensor will lose heat in proportion to the humidity present. The result will be an output voltage difference that gets related to absolute humidity for a given temperature.

Pricing in large quantities is in the $5 area. This sensor would seem to work best where enough power (half a watt) is available to keep it up at its operating temperature, and where an output computer can do all of that linearization and absolute-to-relative humidity conversions for you.

Since absolute humidity is being measured, your operation should be equally good for a low, medium, or high relative humidity range.

The same company offers thermistors for temperature measurement and for air flow measurement using *hot wire anemometer* techniques. Lots of free data sheets, price lists, and ap-notes are available on request.

One handy source of ready-to-use industrial grade humidity sensors is *General Eastern*. *WeatherTronics* is a second.

A final company that does have a very wide line of humidity sensors is *Omega Engineering*. There stuff is usually very expensive, but be sure to pick up their free catalogs.

Two good sources for technical articles and ads on humidity sensing are *Measurements and Control* and *Pollution Equipment News*.

For our second contest this month, just tell me how or why you would like to measure either the relative or absolute humidity.

A Low-end Digital Compass

We've looked at some solid-state digital flux gate compasses in previous columns. These are probably the best way to electronically measure a magnetic heading. Important uses of solid state fluxgate sensors are for cave mapping, boat and plane navigation, for car compasses, and for satellite dish pointing.

I've recently found out about a much cheaper and far simpler method for electronic sensing of a magnetic heading. It is also considerably less accurate than a fluxgate and, being a moving mechanical device, has all of your typical compass damping and hunting problems.

This is the *Dinsmore digital compass sensor*. It is available for $10 in hacker quantities and much less in production quantities. The sensor consists of four hall effect transistors facing at each other and a moving central magnet on a carefully damped pivot. The maximum theoretical resolution is plus or minus 22.5 degrees.

The intended market is for low end auto and bike compasses, but there should be plenty of other low end, robotic, and toy uses.

A simple four LED display is shown in figure five. A liquid crystal display showing N, NE, E, SE, S, SW, W, and NW is also available. This uses the same sensor in a slightly more complex circuit.

For our third and final contest this month, just show me some new or unusual use for a low accuracy but very cheap digital compass.

Replacement Integrated Circuits

There are two different types of transistor and integrated circuit supply houses. The *industrial* suppliers are those that you are most familiar with, and include many of our **Radio Electronics** advertisers.

On the other hand, there are outfits specially set up to handle the *entertainment electronics* devices, that are intended for serice and replacement use in television sets, VCR's, home audio, and such. While the components may end up identical, the part numbers may be wildly different. So might be your availability in small hacker quantities.

Two big sources that every hacker absolutely must know about are the *ECG* people and those *NTE* people. These competing outfits have fat $5 catalogs that list plenty of transistors, diodes, and integrated circuits.

Most importantly, they also list the

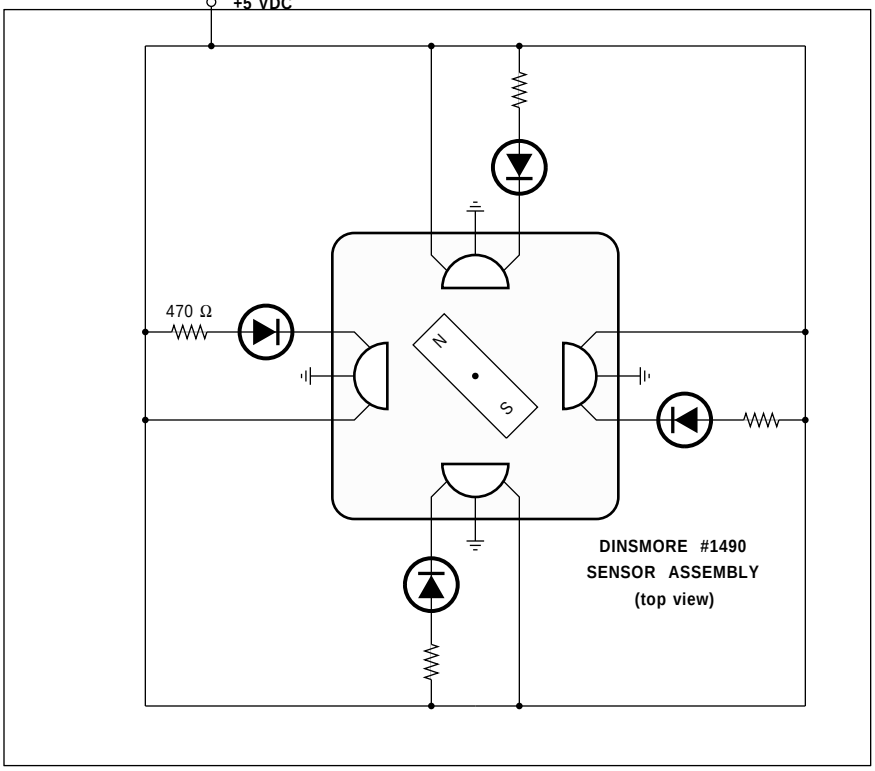


Fig. 5 – LOW END DIGITAL COMPASS is cheaper than a fluxgate but has a very poor resolution. Hall effect sensors are used to drive the LED outputs as shown here. Eight point LCD compass rose displays are also possible.

HUMIDITY SENSING RESOURCES

Abbeon-Cal
123 Gray Avenue
Santa Barbara, CA 93101
(805) 966-0810

Edmund Scientific
101 E Gloucester Pike
Barrington, NJ 08007
(609) 573-6250

Fair Radio Sales
Box 1105
Lima, OH 45802
(419) 223-2196

General Eastern
50 Hunt Street
Watertown, MA 02172
(800) 225-3208

Heathkit
PO Box 1288
Benton Harbor, MI 49022
(616) 982-3200

Measurement & Control
2994 West Liberty Ave
Pittsburgh, PA 15216
(412) 343-9666

Mitsubishi/Shibaura
520 Madison Ave
New York, NY 10022
(212) 605-2146

Omega Engineering
Box 4047
Stamford, CT 06907
(203) 359-1660

Panametrics
221 Crescent St
Waltham, MA 02254
(617) 899-2719

Phys-Chem Scientific
36 West 20th Street
New York, NY 10011
(212) 924-2070

Pollution Equipment News
8650 Babcock Blvd
Pittsburgh, PA 15237
(412) 364-5366

Weathertronix
1165 National Drive
Sacramento, CA 95834
(800) 824-5873

industrial part equivalents. While their pricing is usually higher than the industrial sources, they will gladly sell in single quantities and usually have a very broad selection in stock.

It is also lots of fun to browse on backwards through the simplified chip schematics in these catalogs. Often, you can pick up off-the-wall new use applications for many of the circuits shown.

Be certain to check this pair of catalogs out thoroughly. They are just about indispensable.

New Tech Literature

New data books this month include the "must have" *TTL Logic Data Book* from *Texas Instruments*, that *LSI Products Data Book* from *TRW*; a *Specialty Memory Products Data Book* from Advanced Micro Devices, and a major upgrade of the *Smart Analog Data Book* from *Crystal Semiconductor*. This last jewel has some outstanding digital audio integrated circuits in it.

A $15 kit full of tilt and impulse switches is now available from *Fifth Dimension*, while a free new PLC-V8 Design Kit is available from *Signetics* that involves their new *erasable* logic arrays. Free electroluminescent lamp samples are available from *Nordic Lite*, while free force sensing resistor cards are provided by *Interlink Electronics*.

Three free samples of *Motorola* TMOS power control transistors are newly available through *Hall-Mark Electronics*. They also offer Motorola's *Specs in Secs* IBM compatible data disk at no charge. As always, do make your sample and other freebie requests on your own laser printed business letterheads.

Some really great used computer bargains, Apple and otherwise, are available through Richard Harold of *Shreve Systems*. They are now selling brand new *Franklin* keyboards at $12 each in singles.

A premounted strain gauge useful for electronic scales and whatever is available from *Revere* as their model FT-30 force translator transducer. It is available in ranges from 1 up to 40 pounds, and in resistances from 0.5 to 25 ohms.

The *Hewlett Packard Journal* is a good free source of technical details on sophisticated electronic devices. Their old February, 1987 issue had a good tutorial on wide range optical and infrared sensors in it.

Speaking of IR sensing, *Amperex* has some miniature and sensitive pyrolitic infrared detectors whose prices start at $3.50. This looks like a really great component, but I have not yet had the chance to test them yet. One obvious application is in "hot spot" detectors for use by the fire service. Current devices are ridiculously expensive and many of the volunteer fire departments simply cannot afford them.

For some new information on electronic noise, and noise diodes for testing in particular, check out the *Micronetics* noise diode brochure. There's also a good tutorial on noise and noise testing included.

The leader in charge controlled device CCD image sensors is now *Reticon*. But *Texas Instruments* has their TC210, 220, 230, and 240 sensors and evaluation kits available, which include a 488 x 754 full color RGB evaluation board.

Others introducing new and lower cost CCD devices include *RCA* with their SID504DD device, along with several new devices from both *Tektronix* and *Kodak*.

Turning to mechanical samples, free baggies of vinyl dipped products are gotten through *PMP*. One great place to pick up free samples of any mechanical goodie is through *New Equipment Digest*.

The new trade journals this week include *Surface Mount Technology* and *Electronic Manufacturing*. As usual, you can qualify with your own laser printed business letterhead.

For those of you that want or need more info on all my book-on-demand publishing, there's my *Ask the Guru* reprints, volumes I and II, and the *Hardware Hacker* reprints for this column series. We also stock lots of PostScript books, software, and even videos. The *Hardware Hacker* help line may also be used for PostScript, book-on-demand and laser printing help or networking.

Note that there are once again two *Names and Numbers* sidebars for this month, one for the humidity stuff and one for just about everything else.

Let's hear from you.✦

Don Lancaster's

Hardware Hacker

October, 1989

Solid state visible laser
Laser hacking resources
Picking a filter capacitor
Stereo wireless broadcaster
International power standards

We seem to have a pair of really unusual new hacker components for this month. One is a micropower FM stereo multiplexer, while the other is a solid state red visible laser diode. But first, let's discover a real simple answer to what does seem to be an unduly complex question . . .

Ripple Filter Capacitors

How do you pick the correct value of ripple filter capacitance for a line operated power supply? Some of the older textbooks will give you wildly wrong curves that just do not apply to today's circuit components.

But, I will let you in on an insider secret – you can *instantly* choose the right value of filter capacitor for any line operated power supply simply by memorizing a unique capacitor value of 8300 microfarads and then remembering an ultra-simple rule.

These days, you usually will use a *brute force* capacitor ac input power supply driven from a pair of silicon rectifiers or else a full wave silicon rectifier bridge. One or more voltage regulators will normally get placed between your brute force supply and the actual use circuit.

Figure one shows you two typical line operated full wave power supplies. We'll assume a transformer is used to drop the voltage down to an acceptable value. You could use a center tapped transformer and two diodes, or else an untapped transformer winding and a four diode full wave bridge.

In figure 1-a, your peak output voltage will equal 0.7 times the full rms transformer secondary voltage under load, minus a volt or so for the diode drop. In figure 1-b, the peak output voltage will equal 1.4 times the rms transformer secondary voltage under load, minus two volts or so for the series drop of two diodes.

For instance, if you are using a 12.6 volt rms center tapped filament transformer in the figure one circuit, the output voltage will be 12.6 x 0.7 -1 = 7.8 volts dc peak voltage. In the real world, you'll allow a tad extra and expect a little less.

Contrary to a popular belief, those diodes do *not* conduct for an entire half cycle. In fact, each diode will intensely turn on very briefly during the *middle* of each half cycle, thus delivering a large current slug into the filter capacitor.

Figure two shows you the actual and the simplified ripple waveform across your capacitor. Normally, you will want to design for some reasonable amount of ripple. Otherwise the capacitor value gets too high and the current slugs through the diodes get excessive. You do have to make sure that the ripple troughs do not crash into your regulator headroom.

What happens is that a diode will only turn on when its input voltage exceeds the capacitor voltage. This will only occur briefly at the very center of each half cycle. Twice each ac line cycle, that capacitor will quickly charge. It will then discharge for the rest of the half cycle. The discharge rate is determined by the load resistance, or else by the load current drawn by the regulator and the circuit being powered.

Let us make several simplifying assumptions which can clean up this waveform to make it much easier to analyze. Let's assume that the capacitor can charge instantly and then discharges linearly. Both of these assumptions are conservative and will give us a capacitor value slightly higher than we really need.

But this is a plain old sawtooth wave. During the discharge time, we can assume a linear current and our capacitor will follow the rule…

$$i = C\ \Delta v/\Delta t$$

Here i will equal your discharge load current in amperes, C is your capacitor value in Farads, and Δv is the change in output voltage over a time change of Δt.

Let's rearrange this equation a tad, since we are now looking for the capacitance value …

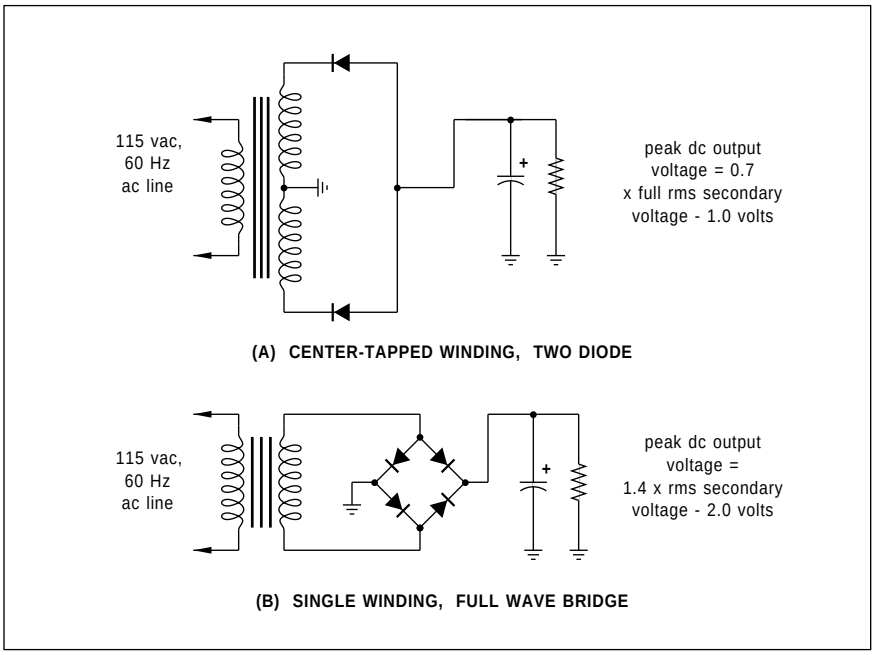


Fig. 1 – TYPICAL FULL WAVE LINE OPERATED "brute force" dc power supplies. Picking the correct value for a ripple filter capacitor turns out to be a lot easier than you might first suspect. The resistor represents a voltage regulator or other circuit load.

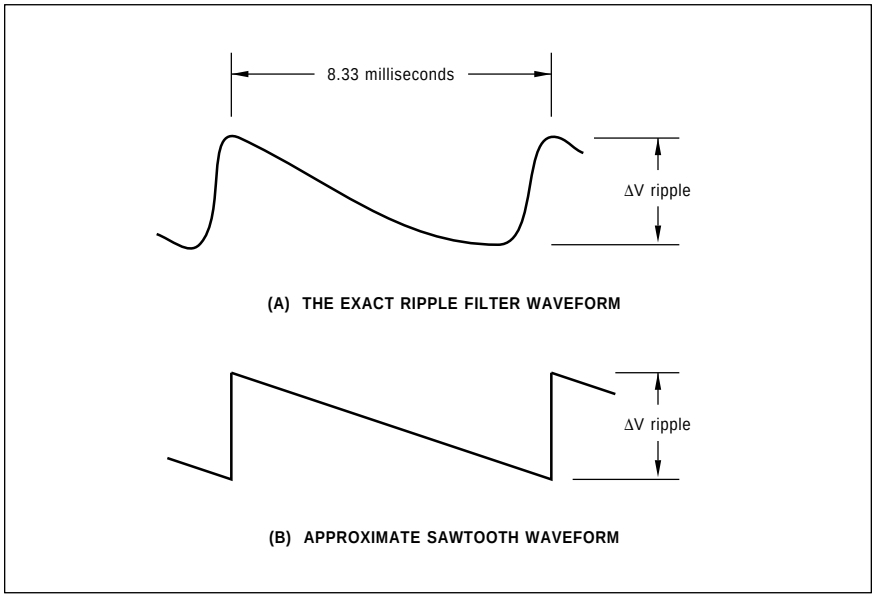


Fig. 2 – THE EXACT AND APPROXIMATE voltage waveforms as found across the ripple filter capacitor. Note that the diodes only conduct very briefly during the middle of each ac line half cycle.

$$C = i\,\Delta t/\Delta v$$

$$8300 \times 700/1000 \times 1/3 = 1917\ \mu F$$

Next, let us assume we have one amp of load current and discharge one volt during a half power cycle, which equals 1/120 Hz or 0.00833 seconds or 8.33 milliseconds. That magic capacitance value that handles this is 8.33 millifarads, equal to 8330 microfarads. Say 8300 µF for short.

Which leads us to the magic rule of figure three: In an 8300 microfarad capacitor used in a full wave line operated supply, *the volts of ripple will equal the amps of load current*.

Now for the neat part. Any other capacitor value is found by a simple scaling. You do not even need to use a calculator.

For instance, an 830 µF capacitor will yield one volt of ripple with 100 milliamps of current drain. A 1660 µF capacitor will give you one volt of ripple for 200 milliamps of current.

Or to get slightly fancier, a 700 mil supply allowing three volts of ripple will need a capacitor value of …

Call it an even 2000 µf to round off to the next highest stock value.

The capacitance value will vary *directly* with your load current and *inversely* with the allowable amount of output ripple.

Do not, under any circumstances, mention this insider secret to your electronics teacher. He will fail you for suggesting such an absurdly simple rule. Especially since your value will be correct and his will not. But then again, two semesters from now, he will try teaching this heretical and super elegant method. But only to his best students.

What about half wave supplies that use only a single diode? Just *double* the capacitor values from the above calculations, and you are home free.

In an 8300 Microfarad Capacitor, the VOLTS of ripple will equal the AMPS of load current.

Fig. 3 – MEMORIZE THIS MAGIC VALUE and then do a simple scaling to instantantly calculate the correct size filter capacitor. For half wave supplies, simply double the final capacitor size.

A Stereo FM Broadcaster

As we found out last month, *Rohm* is an outstanding hacker source for unusual integrated circuits. And one that's super hard to find, since they have not been advertising very much in the trade journals.

Anyway, I finally did get a few samples and data on their BA1404 FM stereo modulator chip.

This is a single integrated circuit which could convert two high quality stereo audio channels into a miniature FM broadcast band transmitter output. Since the chip needs only three mils from a 1.25 volt supply, it is also ideal for new wireless microphones, survellience devices, and for other low power broadcast uses.

Seperation can be 45 decibels and a flatpack version is available for miniature applications.

Another intended use is to accept the stereo output of a CD player and broadcast it to an FM car radio, without needing any special add-on connections between the CD player and the receiver.

You should also be able to use this for some offbeat applications, such as model rocketry, telemetry, computer data linkups, CB communications, or for remote controls.

A typical broadcast range is 50 to 100 feet. Figure four shows you one possible schematic.

The two audio channels go in by way of a typical FM pre-emphasis network. A 38 kHz crystal is used to create the L-R stereo mul- tiplexed signal, which is routed to an internal varactor-tuned RF oscillator that operates in the 88 to 108 MHz range. That modulated oscillator sig- nal is then sent to a final isolating rf amplifier and then gets routed to an antenna. The RF output voltage is around 600 millivolts.

Cost of the chip is around $1.50, and free engineering evaluation samples are often available on letterhead requests. Several **Radio-Electronics** classified advertisers offer ready-to-go component kits and printed circuit boards for this circuit.

Laser Resources

Until recently, I guess I was pretty much down on the laser people. After all, these turkeys have had over 25 years to get their act together, and the best they have offered us hackers are some overgrown neon lamps that are fragile, insanely overpriced, grossly inefficient, short-lived, color limited,

hard to power, and harder yet to linearly modulate.

Worse yet, our $49.95 home shop radial arm laser is nowhere in sight, and worst of all, that ongoing SDI starwars atrocity is giving the entire laser industry a bad name.

But things just might be changing. There are a few new developments, especially several new high volume solid state *visible* laser diodes that should drop down into the $5 range in a year or two. So today just might be a good time to review some laser resources suitable for hardware hacking. Several of these appear over in the *Laser Resources* sidebar.

So what's the big deal about lasers and lasing? A laser is nothing but a light bulb. Apply power and it puts out light. The light gets created by exciting electrons to a higher energy level through a *pumping* process. As the electrons drop back down to their normal energy levels, they output a precise packet of light energy.

There are several very interesting properties of laser light that let lasers solve problems that can be difficult or impossible to do otherwise…

Laser light often turns out to be *monochromatic*, meaning it is all one color, just like a single pure audio tone or radio carrier. Which quickly leads to such things as red, blue, and green projection televisions or for computer displays. Or for color laser printing, laseriums or rock concerts.

Monochromaticity is also useful for chemistry and pollution control, where some reactions take place best at very specific light wavelengths.

Monochromatic light is very easy to focus into a continuous and non-divergent beam. Such a beam of light is called a *collimated* beam. Think of it as a non-sagging red string you can point anywhere you like.

Now, ordinary light bulbs obey an *inverse square law*, which means that if you double the distance, you only get one quarter the intensity, and so on. But with a collimated beam, you can sometimes gather in your *entire* beam at the receiving site.

In theory, square law losses can be entirely eliminated. In practice, they can be dramatically reduced. Thus, a laser gives us *unattenuated action at a distance*. Which leads us to blackboard and lecture pointers. Or survey gear. Or construction levels. Out here in Arizona, cotton farmers use laser beams to precisely level all of their irrigation fields to one inch per acre or less, very much reducing their need for irrigation water.

Collimated laser beams can also be used as *aiming devices*, both for use on weapons or for supermarket bar code readers.

Some laser beams are not only monochromatic, but they also will maintain a very precisely controlled phasing over their entire beam. This leads to *coherent* light. Important uses of coherent light are for creating and viewing of a three-demensional *holographic* image, or for the super precise measurements of extremely small distances.

As an example, one of *Hewlett Packard's* favorite photos is an end-supported six inch thick "I" beam. Their laser *inferometer* will easily measure the deflection sagging of the beam as the weight of a single dime is added or removed. Other uses of laser inferometry include earthquake detection, solid state gyroscopes, and for the generation of extremely short power pulses.

Most laser beams are not all that powerful. But that power can now be concentrated over a very small area, leading to a very high beam *power density*. For instance, a 5 milliwatt laser imaged on a 1 mil spot has an energy density of 8 kilowatts or so per square inch, or over *one megawatt per square foot!*

Which in turn can lead us to laser welding and cutting. Medical uses include blasting out clogged arteries or optically rewelding detached retinas in place. Industrial uses include both welding the unweldable and precision cutting to extreme accuracy. Artistic uses include laser carving of wood or plastics, and the upgrading of diamond quality by zapping any included impurities.

A rather interesting new use for high energy density ultraviolet laser beams involves *stereo lithography*, where three dimensional objects are selectively hardened out of a liquid photopolymer resin. This can be the ultimate *Santa Claus* machine where a plastic copy of anything can be replicated any place and any time. Detroit modelmaking time can drop from months to minutes with stereo lithography. *3-D Systems* is a major supplier of this sort of thing.

Some laser beams can be rapidly turned off and on at high frequencies. We say the beam is *modulatible*. By turning the beam off and on, we can

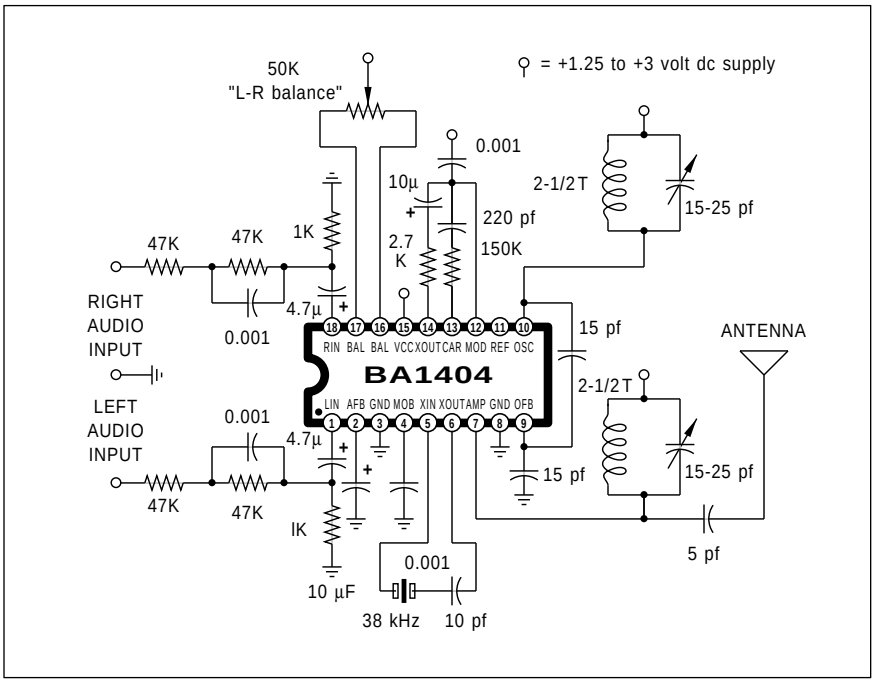


Fig. 4 – A MICROPOWER STEREO FM wireless broadcaster that is low in cost, works off one AA cell, uses few parts, and offers high audio quality.

LASER RESOURCES

Applied Laser Tech
7707 East Acoma Drive
Scottsdale, AZ 85260
(602) 483-1214

Edmond Scientific
101 E. Glouchester Pike
Barrington, NJ 08007
(609) 573-6250

Fiberoptic Product News
301 Gibralter Drive
Morris Plains, NJ 07950
(201) 292-5100

Fiberoptics World
1421 South Sheridan
Tulsa, OK 74112
(918) 835-3161

Heath Company
PO Box 1288
Benton Harbor, MI 49022
(616) 982-3200

Herbach & Rademan
401 E Erie Avenue
Philadelphia, PA 19134
(215) 426-1700

Jerryco
601 Linden Place
Evanston, IL 60202
(312) 475-8440

Laser Focus World
1421 South Sheridan
Tulsa, OK 74112
(918) 835-3161

Lasercraft
PO Box 696
Santa Rosa, CA 95402
(707) 528-1060

Lasers and Optronics
Box 650
Morris Plains, NJ 07950
(201) 898-9281

Meredith Instruments
6403 North 59th Avenue
Glendale, AZ 85301
(602) 934-9387

Nuts and Volts
Box 1111
Placentia, CA 92670
(714) 632-7721

Photonics Spectra
PO Box 1146
Pittsfield, MA 01202
(413) 499-0514

Sharp
Sharp Plaza
Mahwah, NJ 07430
(201) 529-8757

3D-Systems
26081 Avenue Hall
Valencia, CA 91355
(818) 898-1533

Toshiba
9775 Toledo Way
Irvine, CA 92718
(714) 455-2000

place information on to that beam. Three of the highest volume uses of lasers are for CD players, for desktop publishing printers, and for fiberoptic communication. All of these crucially depend on laser beam modulation.

So where can you start? Far and away the best source of hacker laser parts in the country is *Meredith Instruments*, who also have a new light show BBS up and on line at (602) 867-7258. Their competitors include *Herback and Rademan* and *Jerryco*, along with a number of other sources that advertise in *Nuts and Volts* and right here in **Radio-Electronics**.

The really big news is that new TOLD-9200 visible red solid state laser by *Toshiba*. These dudes are now in volume production, are easy to modulate, rugged, last forever, and are simple to battery power. And costs should ridiculously drop in the future. Among its numerous other features, this new product can single handedly quadruple the storage on a CD disk or double the resolution of a desktop publishing laser printer. Not to mention that you can actually see where the beam is pointing.

Sharp has a very interesting *Laser Diode User's Manual* out. This one is both free and an essential resource. Many infrared laser diodes now have built-in photodetectors, so a feedback loop can be used for stability.

Two obvious sources of education laser stuff include both *Heathkit* and *Edmund Scientific*. Picking a few names at random, *LaserCraft* does beautiful wood carvings for yuppie desk accessories, while the *Applied Laser Tech* folks do have some interesting laser engraving machines you might want to check into. And, as we have seen, *3-D Systems* is now in the center of laser stereolithography.

There are a number of free laser trade journals. Four of the more useful laser include *Laser Focus World*, *Lasers & Optronics*, *Fiber Optic System News*, and *Photonics Spectra*.

Foreign Power Supplies

I've now gotten several calls from people who want to take all their computers overseas or to some other country, and were asking about the power line voltage and frequencies, the connectors, the video standards, adaptors, and so on.

Well, the overwhelming majority of the civilized world runs on 220 volt 50 Hertz power using strange power connectors.

The bottom line is this: Do *not* take your computer out of the country. Ever. The hassles, both electrical and bureaucratic, will eat you alive. Rent or buy a local computer when you get there instead.

There's an outfit known as *Panel Components Corporation* who have issued a new and free *Export Designer's Reference and Catalog #5*.

This beauty can show you which connectors get used in what country, and lists the standard voltages and frequencies for pretty near every country in the world. Even Svalbard (220 volt, 50 Hz, Schucko plugs) and Burkina Faso (220 volt, 50 Hz, ungrounded eurocord) are included. A complete list of all the world-wide standards organizations and regulatory agencies are also provided.

New Tech Literature

New data books for this month do include the *Lamda Semiconductors Databook* on high curent power supply regulators, and controllers; and a *Memory Databook* from *OKI*. *SGS* has a pair of application books out, one on *Zero Power Memories* and a second on Cache Memories.

Free electronic evaluation samples include the LM6321 op-amp from *National Semiconductor*. This is a higher performance replacement for their old hybrid units, usable for video and fast gain blocks. *Xicor* is also offering free samples of their X2402 electrically erasable PROM, organized as 2K x 8 over a two-wire serial interface.

Murata has a wide selection of surface mounting kits in stock, even including a free packet of surface mountable ceramic capacitors. Some interesting and sanely priced rf coil designer and current sensor kits are available from *Coilcraft*.

Free samples of rubber and plastic tubing useful for pneumatic robotics is available from *Hygenic*. And two free publications from *Maxim* should prove most useful, namely the *Maxim Engineering Journal* and the *Maxim Design News*.✦

Don Lancaster's

Hardware Hacker

November, 1989

More on cold fusion
New PostScript video
Linear stepper motors
Stepper driver circuits
Modelmaking resources

Is cold fusion for real? Most of the researchers and most of the labs loudly have decided "no" after all of their initial hasty and misdirected experiments failed. But a very few labs are now more convinced than ever that something big is coming down.

At any rate, sources very close to the barber of an associate of a usually reliable spokesperson for a key fusion researcher feel that . . .

(1) Cold fusion is real and is in fact the explanation for both the continuous and "burst modes" of the excess heat production.

(2) The tritium reaction does all of the work, and enough tritium is produced to exactly be able to account for the excess heat.

(3) The ambient air can poison the reaction. Working in a very dry inert argon atmosphere is recommended.

(4) The palladium must be vacuum refined and then recast, but *not* in a carbon mold. Any rework, such as an extrusion, is a not allowed.

(5) While palladium films as thin as 50 angstroms could be used, any impurities at all are a no-no. In particular, platinum impurities as low as 0.01 percent spoil the material.

(6) All bubbles must absolutely get eliminated at the palladium surface. Pressurizing the heavy water can help bunches here.

(7) The deuterium ions must flow *through* the Palladium. One approach might be to use a sintered palladium cylinder having an internal vacuum. Another might involve a three element cell with an accelerating *second anode* of some sort.

(8) Operation above 175 degrees will dramatically drop the efficiency. Thus, a heat engine using some non-water fluid, such as ammonia, must be used to extract useful work. Fortunately, those OTEP (ocean thermal electric power) people have already done all the groundwork for low temperature differential heat engines.

(9) For a breakeven, excess fusion heat production well beyond 12:1 will probably be required, due to the inherently low efficiency of any heat engine forced to work with a low temperature differential. Thus, a little bit of excess heat is useless except possibly as a yuppie ski boot heater.

(10) Other candidate materials do include zirconium, lanthanium, and titanium, but titanium does seem very overrated at present.

(11) Yet another reasonably priced source for heavy water is that *Canadian Atomic Energy Commission*. I do not have their address so far. A free book if you do.

In reality, most of these observations are straight from the horse's whatever. Time will tell us which end of the horse we are dealing with.

Meanwhile, besides all the original German work from the early 1920's, there is an obscure 1979 Australian patent #48901/79 on cold fusion.

While I personally do feel that this patent appears to involve someone who seems to be a few chips shy of a full board, it sure will be interesting to see how many modern claims will be disallowed because of this apparent prior art.

Oh, yes. You might also want to look at US patents 3,983,882 and 4,107,008. Curiouser and curiouser.

On to a popular help line topic . . .

Stepper Motors

There have been a lot of helpline requests lately for extra information on *stepper motors*. A stepper motor differs from an ordinary motor in that it rotates its shaft in a discrete and incremental stepping motion.

A stepper motor is thus ideal for any intermittent or precise motions, such as you would need for the platen feed on a dot matrix or daisywheel printer. Steppers are also useful for any slow speed application, eliminating the cumbersome gear trains you would need with most ordinary high speed motors. The steppers are also instantly reversable, and usually have a holding torque that can act as an internal brake. Steppers are handy for variable speed uses, something that gets extremely tricky to do with most ac motor designs.

One type of stepper motor consists of a toothed magnetic rotor and a toothed iron stator. The number of teeth decides the *step angle* and the number of steps per revolution. In the absence of any electrical input the rotor will *lock* to the stator by seeking out paths of minimum magnetic reluctance.

There are normally two groups of

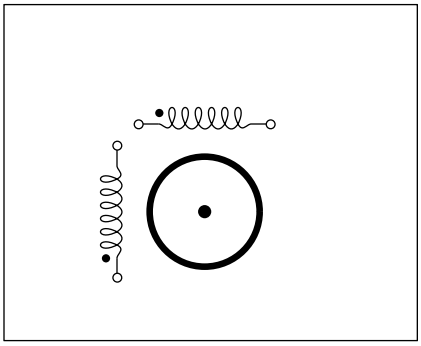


Fig. 1 – IN A BIPOLAR (or unifilar) stepper motor, there is only a single winding for each phase. Although the stepper itself is powerful and low in cost, the driver circuitry gets extra complicated since a full bridge circuit is required that is able to route current in either direction. Bipolar steppers often have four leads.

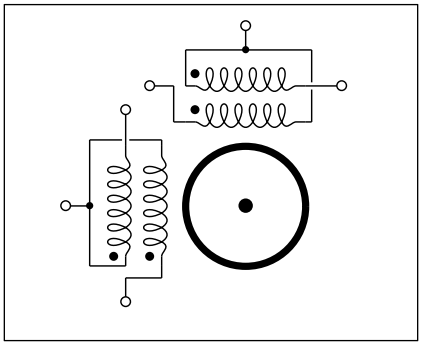


Fig. 2 – IN A UNIPOLAR (or bifilar) stepper motor, you will find a pair of windings for each pahse. While this raises the cost and also reduces the available stepper power, your driver circuitry is vastly simplier and very much cheaper, since only a current sink is needed for each winding. A unipolar stepper often has six leads.

windings provided. The "A" winding is active *one-third* of the distance between teeth, while the "B" winding is active *two-thirds* of the distance between the teeth.

In typical use, a four-step process is used to advance to the next tooth position. The A winding first gets activated, attracting the toothed rotor *one-third* of the distance to the next tooth. Then the B winding is activated, attracting to the two-thirds point. Next, the A winding has its current *reversed* to further repel towards that two thirds point. In the final step, that current in the B winding gets reversed, repelling the rotor to its new and final position.

The speed gets determined by the number of steps applied per second. The direction is set by changing the roles of the A and B windings.

Other patterns of activating the "A" and "B" windings might give you various speed and torque options, as well as actually *microstepping*, the moving to a precise position *between* the rotor teeth.

As figures one and two show us, there are two different methods with which stepper motors are commonly wound. In a *bipolar* stepper there is only a single A winding and only a single B winding. This is cheaper and has more power, but requires you to electronically *reverse* the high current through both windings. Thus, what you gain in stepper economy, you loose in driver complexity.

In a *unipolar* or a *bifilar* stepper, there are two distinct A windings and two separate B windings. Each of the windings go in the opposite sense of the other, so a current in one winding will attract the rotor, while the same current in the other winding will instead repel the rotor.

The unipolar windings are much easier to drive, but do cost more and will offer less power.

You can usually tell which type of stepper you have by the number of leads. Assuming that all the leads are brought out separately, a bipolar stepper will have four wires, while a unipolar one will have six. For most hacker uses, the unipolar and bifilar windings are the overwhelming best choice, since they are far easier and cheaper to drive.

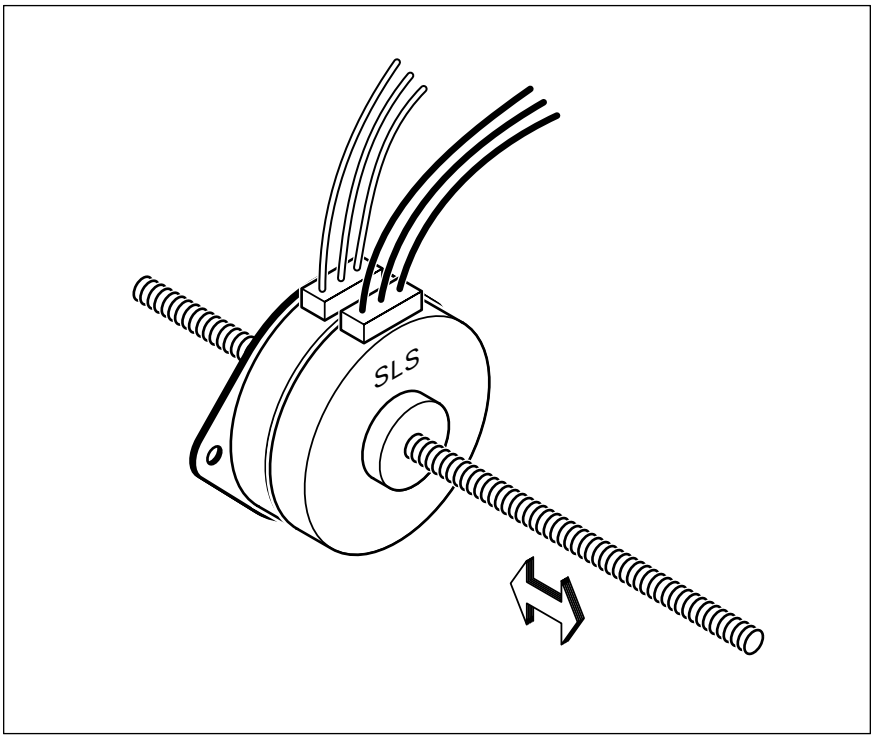


Fig. 3 – THIS HURST SLS LINEAR ACTUATOR is a real "sleeper" for new hardware hacking. This easy-to-drive 12 volt, 12 watt unit offers 24 pounds of force in two mil increments. Use them in pairs for X-Y motions. What can you do with these that are new and unique?

Good data sheets and ap-notes on steppers are available from *Airpax*, *Hayden*, *Superior Electric*, and most of the other suppliers. Bunches of technical articles and supplier ads for steppers appear in the *PCIM* and *Motion* trade journals, as well as the usual electronics insider magazines.

While new steppers are usually rather pricey, you can find lots of surplus ones in assorted sizes and voltages for as little as $2 through all the usual **Radio-Electronics** ads and similar surplus sources.

Two Linear Steppers

Take an ordinary stepper motor, but make it hollow at its center. Then add a threaded shaft through the middle, which gets driven from a nutplate on the stepper armature. As the stepper is stepped, the nutplate turns, which in turn advances or retards the threaded shaft.

All of which gives you a way to push or pull things in tiny and very accurate increments under computer control. With lots of force over fairly long strokes.

Uses? Animation tables. Printed circuit drills. A numeric controlled milling machine. Plotters. Robotics. Valve actuators. Electronic engine controls. Research projects. Point of purchase displays. Plus dozens of uses previously unthunk of.

Figure three shows you the *Hurst* model SLS linear actuator. This one is a twelve watt unit that gives you 25 pounds of force in two mil (.002 inch) increments over an eight inch actuating length.

While under $20 in quantity, single evaluation units do cost around $55, unless you can locate a surplus one. Which seems rather high, until you take that "Uh, Compared to What?" factor into account.

On custom order, lead screws up to several feet long can be obtained. Note that there is no theoretical limit to the stroke you could get out of one of these, so long as a lead screw that length is available. Maintaining the precision and avoiding any binding would, of course, get far worse with increasing length.

Figure four shows you a smaller *Airpax* series 92100 unit. These are much smaller and give you a half inch maximum stroke, in two or four

mil steps, having a force slightly over one pound.

The price is around $25 each, but you might be able to find one nearly free at your local junkyard, as some automobiles do use these devices for all their computerized carburetor idle adjustments.

Unfortunately, I just don't know which specific models to send you after. There are also some plain old throttle solenoids that look about the same as these, so make sure you are getting a "real" stepper when you make your visit.

You can step these up to 400 steps per second, which means you can travel the half inch stop to stop distance in something like 0.6 seconds. But you do loose force at the higher stepping rates.

On other models, you can get other pitches on the lead screws, which lets you trade off your resolution per step against the speed of travel.

We are using this one locally to adjust the teeth on a cotton picking machine. The stepper acts as sort of a micrometer, advancing until it will touche each tooth. The number of steps needed then tells the mechanic how much shim to add.

If you could not care less about cotton picking, what we have here is an easy and precise way to eliminate a most tedious and time-consuming job. If the teeth are too close, you destroy the machine. If they are too far away, your yield and your grade goes down.

A third source of linear actuators is *Eastern Air Devices*, but their military look and their refusal to include pricing in their mailings does not bode well for hackers.

Stepper Drivers

Most of the stepper manufactueres have available driver circuitry for their devices, but these tend to be older hybrids that seem overpriced. Instead, there are several suppliers of single and double chip stepper motor drivers. These include *Sprague*, *SGS*, and *Motorola*.

Figure five shows you a circuit for the *Sprague* UCN-4204B single chip stepper driver. While I haven't yet been able to check this chip out (stay tuned), it looks like a typical modern circuit with 1.5 amps of drive capability and internal protection for both overheating and overcurrent. These are well under $4 in singles.

To use this circuit, you provide two inputs. The first is the direction input which decides whether your stepper will spin forwards or backwards. The second is a train of square wave pulses that sets the speed you will travel in the chosen direction.

It is usually best to computer control your stepper driver. As we've seen, an otherwise unused *Commodore 64* is ideal for this sort of thing, and their going rate is around $30 at a yard sale.

One microcontroller chip that I really like which includes dual low level stepper drivers on-chip (among lots of other goodies) is that great M50734 by *Mitsubishi*. This dude cross assembles beautifully on an Apple IIe or IIgs.

Three Contests

Let's have three contests for this month. There will be the usual *Incredible Secret Money Machine* book prizes for the best dozen entries, with an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all.

For the easy contest, just tell me something you would like to do with a linear stepping motor or a linear actuator. Or two or even three. Especially if they have twenty pounds of force in two mil increments.

For our intermediate contest, just tell me which makes and models of automobiles use linear stepping actuators as their idle controls.

For the hard contest, nobody talks very much about the electrical and mechanical *efficiency* of a stepping motor. *Why?*. Could a very large and extremely efficient linear stepping motor get built?

This would dramatically improve solar water pump design, as the pump stroke and speed could be exactly and continuously matched to both the available input solar power and the well characteristics. Which might enormously simplify and cheapen both the electronic and mechanical designs. Especially for remote and third-world applications.

Let me know any of your hardware hacking thoughts on this.

Modelmaking Resources

In any large electronics company, the *model shop* is that secret lair where all of the mockups, mechanical prototypes, breadboards, concept pieces, and one-of-a-kinds come from. As a hacker, you are your own

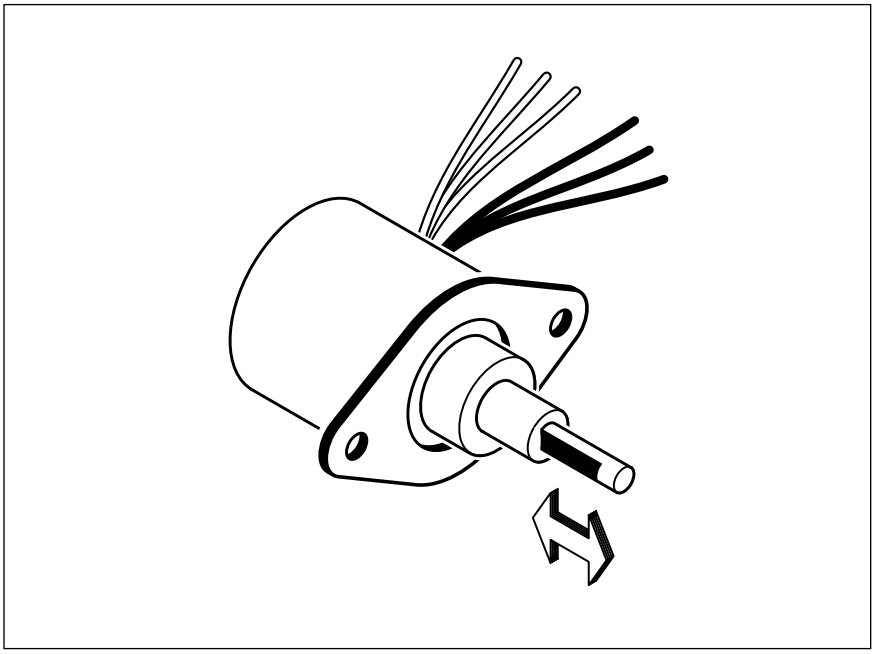


Fig. 4 – THE AIRPAX 92100 is a smaller linear stepper motor having a 1/2 inch stroke. Somewhat similar units may be available at your local junkyard as throttle idle controllers.

model shop, so it is super important to know where to go to get all of the non-electronic bits and pieces you'll need to make hacking more hackable.

Our new *modelmaking resources* sidebar shows you a few places to go for model info and supplies.

Naturally, you will want to check out your own local resources first. These should include a good hardware store, a large junkyard, a real hobby shop, and a few electronic surplus houses that do *not* have a catalog and do *not* advertise in any national magazines. One regional example around here is the *Apache Reclamation and Salvage*. Ask any ham radio operator for a complete neighborhood list.

I've also found a local horse trailer factory to be useful, especially when it comes to cheaply finding, shearing, and bending any heavier metal. You might want to substitute an air conditioning outfit, a welder, or even a blacksmith shop here.

At any rate, one resource stands out head and shoulders above all others for hacker modelmaking. This is *Small Parts*, who stock everything your hardware store never heard of, besides custom cutting small pieces of metal and plastic for you. All at fair costs, selling to anyone with very low minimum orders.

A second major resource would have to be *JerryCo*, who do have a mind-boggling assortment of low priced mechanical and electronic surplus stuff. Competitors to JerryCo include *Edmund Scientific*, *BNF Sales*, *Herbach and Rademan*, and *C&H Sales*. Along, of course, with many of our other superb **Radio-Electronics** advertisers.

The "super hardware stores" that industry shops at include *McMaster-Carr* and *W.W. Granger*, both of whom do have warehouses in most major cities. I guess I'd have to also include *Stock Drive Products* here for timing belts, gearing, and such, although their pricing is often on the high side.

While I know of no magazine or trade journal aimed directly at hacker modelmaking, seven of your "must have" publications do include *Model Railroader*, *Fine Scale Modeling*, *Design News*, *Machine Design*, *Nuts and Volts*, *Signcraft*, and the *New Equipment Digest*. Don't tell NED who told you about all their great free samples each month.

For a wide-ranging assortment of fairly priced books on all aspects of prototyping and modelmaking, *Lindsay Publications* is a good choice.

Let us see. For all the materials themselves in smaller sizes, Try *K&S* for metal sheet, rod, and tubing; the *Evergreen* folks for custom cut vinyl; *NorthEastern* for wood shapes that are precision precut into the magic sizes favored by model railroaders, architects, and doll house builders; and *Milled Shapes* for any miniature brass extrusions.

For larger wood stuff, check into *The Woodworker's Store*, *Constantine*, or *Edlco*. Nothing sharpens up a prototype case better than making it from an exotic wood such as Bocote, Wenge, Cocobolo, or Padouk.

It used to be that cardboard was cardboard and posterboard was posterboard. But today, there are dozens of easily worked, sturdy, light, and good looking high tech sheet stocks especially designed for models and mockups. One leading distributor of these materials is *Fomeboards*.

Several random companies do fall into the "neat stuff" category, making them extremely valuable resources for modelmaking. Some of these include *Hygenic* for rubber sheeting and tubing; *Caplugs* or *Sinclair and Rush* for all sorts of unique closures; *Plastiglide* and *ITW Fastex* for unusual plastic items; *Bead Chain* for themselves; and *US Plastics* or *AIN Plastics* for plastic stock. Other obvious cheap plastic sources are the *Lexan* glazing sheets from any local glass cutter.

If you do have any modelmaking favorites of your own, please let us know so we can pass them on.

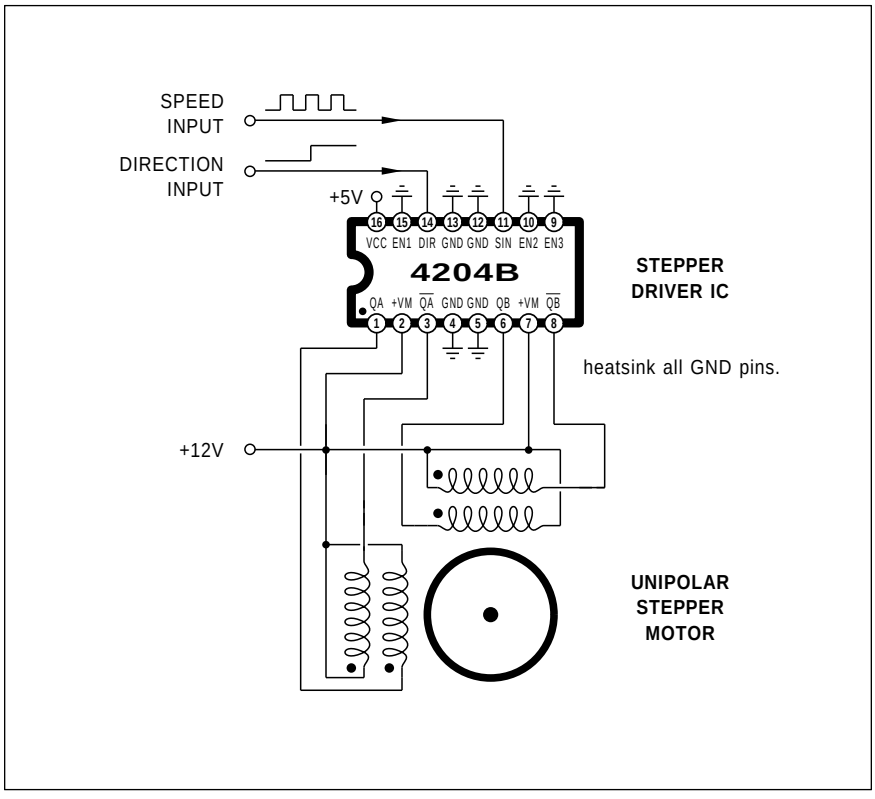


Fig. 5 – LOW COST SINGLE-CHIP stepper motor drivers are readily available from Motorola, SGS, and Sprague. Here is a popular and very low cost Sprague driver circuit.

New Tech Literature

A design for a hackable very low noise FET amplifier appeared in the June 1989 *Review of Scientific Instruments* on page 1194. It is claimed to be 100 times better than anything else available. But note that low noise amplifier design is very much a function of source impedance and

MODELMAKING RESOURCES

AIN Plastics
249 E Sandford Blvd
Mt Vernon, NY 10550
(914) 668-6800

Apache Reclamation
313 W Apache St
Phoenix, AZ 85003
(602) 254-0613

Bead Chain
110 Mountain Grove,
Bridgeport, CT 06605
(203) 334-4124

BNF Enterprises
119 Foster Street
Peabody, MA 01961
(508) 531-5774

C & H Sales
2176 E Colorado Blvd
Pasadena, CA 91107
(213) 681-4925

Caplugs
2150 Elmwood Avenue
Buffalo, NY 14207
(716) 876-9855

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

Design News
275 Washington Street
Newton, MA 02158
(617) 964-3030

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

Edmund Scientific
101 E Glouchester Pike
Barrington, NJ 08007
(609) 573-6250

Evergreen Scale Models
12808 NE 125th Way
Kirkland, WA 98034
(206) 823-0458

Fastex
195 Algonquin Road
Des Plaines, IL 60016
(312) 299-2222

Fine Scale Modeling
21027 Crossroads Circle
Waukesha, WI 53187
(414) 796-8776

Fomeboards
2211 N Elston Ave
Chicago, IL 60614
(312) 278-9200

W W Granger
5959 West Howard St
Chicago, IL 60648
(312) 647-8900

Herbach & Rademan
401 East Erie Ave
Philadelphia, PA 19134
(215) 426-1700

Hygenic Manufacturing
1245 Home Avenue
Akron, OH 44310
(216) 633-8460

Jerryco
601 Linden Place
Evanston, IL 60202
(312) 475-8440

K & S Engineering
6917 West 59th St
Chicago, IL 60638
(312) 586-8503

Lindsay Publications
PO Box 12
Bradley, IL 60915
(815) 468-3668

Machine Design
1100 Superior Avenue
Cleveland, OH 44144
(216) 696-7000

McMaster-Carr
Box 54960
Los Angeles, CA 90054
(213) 692-5911

Milled Shapes
1701 North 33rd Ave
Melrose Park, IL 60160
(312) 344-1220

Model Railroader
21027 Crossroads Circle
Waukesha, WI 53187
(414) 796-8776

New Equipment Digest
1100 Superior Avenue
Cleveland, OH 44114
(216) 696-7000

Northeastern Models
PO Box 727
Methuen, MA 01844
(508) 688-6019

Nuts and Volts
Box 1111
Placentia, CA 92670
(714) 632-7721

Plastiglide
2701 West El Segundo Blvd
Hawthorne, Ca 90250
(213) 777-8108

Signcraft
1938 Hill Ave, PO Box 06031
Fort Myers, FL 33906
(813) 939-4644

Sinclair & Rush
10315 Page Industrial Blvd
St Louis, MO 63132
(314) 426-4487

Small Parts
6891 NE Third Ave
Miami, FL 33238
(305) 751-0856

Special Shapes
PO Box 487
Romeoville, IL 60441
No listing

Stock Drive Products
55 South Denton Ave
New Hyde Park, NY 11040
(516) 328-0200

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

US Plastics
1390 Neubrecht Road
Lima, OH 45801
(419) 228-2242

Woodworker's Store
21801 Industrial Blvd
Rogers, MN 55374
(612) 428-2899

operating frequency. Thus, there is no such thing as a "best" low noise amplifier. Low noise design is also easily trashed by poor shielding or improper grounding and guarding. Other sources of low noise amplifier info include *Precision Monolithics*, *Burr Brown* and *Linear Technology*.

Rohm has a pair of new data books available on all their absolutely outstanding hacker integrated circuits. Try to get the fat Japenese book as well as the thin English one.

Heath Electronics is a brand new hacker publication. They are also looking for authors, but their payment rates are inexcusably chintzy. For more info, contact Ed Mosher at the *Heath Buyers Club*.

A free primer on spectrum analysis is available from *Tektronix*, while *Brookfield* has lots of free ap-notes available on viscosity measurement and control. Call them for a free list.

Needless to say, you'll get the best inquiry and sample results with your own laser printed letterhead or else by making a professional sounding telephone request.

Turning to my own products, I've just finished my new *Introduction to PostScript* videotape, and have now book-on-demand published a series of reprints from my *LaserWriter Corner*, originally found over in the *Computer Shopper* magazine. Included are over three dozen free and unique PostScript fonts. For those of you starting up your own hacker tech venture, you might want to check into my *Incredible Secret Money Machine* book.

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

Don Lancaster's

Hardware Hacker

December, 1989

Optical reprint sources
Hacker pc breakthough
Clock and doorbell chip
Printed circuit resource list
Faking double-sided boards

Our stupendously major new breakthrough for this month is a brand new way of doing hacker printed circuit boards that I'll call the *direct toner method*. Believe it or not, all you need is an iron and your favorite word processor.

This new process is ridiculously faster, simpler, and cheaper than any of the old ways. Since this is so new, we sure could use your personal help in further testing and debugging.

But first, let's review some of the older ways of making printed circuit boards. We might start off by going over some…

Circuit Board Fundamentals

Printed circuit boards first became popular in the early 1950's because of their overwhelming advantages over point-to-point wiring. The pc wiring pattern was always the same, virtually eliminating wiring errors. Stray inductance and capacitance were now much lower and far more uniform. And the manufacturing could now get totally automated. Production times became much shorter, and labor costs sharply dropped. So did size and weight.

A printed circuit board often will consist of an insulating *substrate* that has one or more layers of conducting patterns placed on or in it. Figure one shows us some popular forms of the printed circuit boards.

You will find three main substrate materials in use today. These include phenolic, FR-4 (or G-10) glass epoxy and CEM-1 composite epoxies. While phenolic is the cheapest, it does chip and shatter easily, and should get heated before punching or drilling. It is often used for single sided layouts in toys, appliances, and any other high volume applications. For us hackers, phenolic is nearly useless.

Glass epoxy is pretty near the same stuff a fiberglass boat is made of. It has great electrical and mechanical properties, and is nearly ideal for any double-sided and multilayer boards. Hacker disadvantages are that glass epoxy costs more and dulls drills at an amazing rate. Carbide drills are just about manditory for all but the shortest of production runs.

The CEM-1 material has only a pair of fiberglass layers impregnated into an epoxy body. Being cheaper and easier to drill than glass epoxy, this is a good choice for hacker use. It also drills and punches well. Glass epoxy boards are well suited for all but the most precise and exacting needs. They even come in a wide variety of colors.

The simplest variation is a *single sided* board. The substrate is most often 1/16th of an inch thick, and has a single layer of copper foil laminated to one surface only. Two popular thicknesses of copper are used. *One ounce* copper is around .00135 inches thick, and *two ounce* copper is double that, or around a .00270 inches thick.

Thus, one ounce copper is a tad over one mil thick, and two ounce copper is somewhat over two mils thick. A two ounce copper is normally reserved for higher current uses or where extreme reliability is needed.

On a traditional single sided circuit board, most of the components get

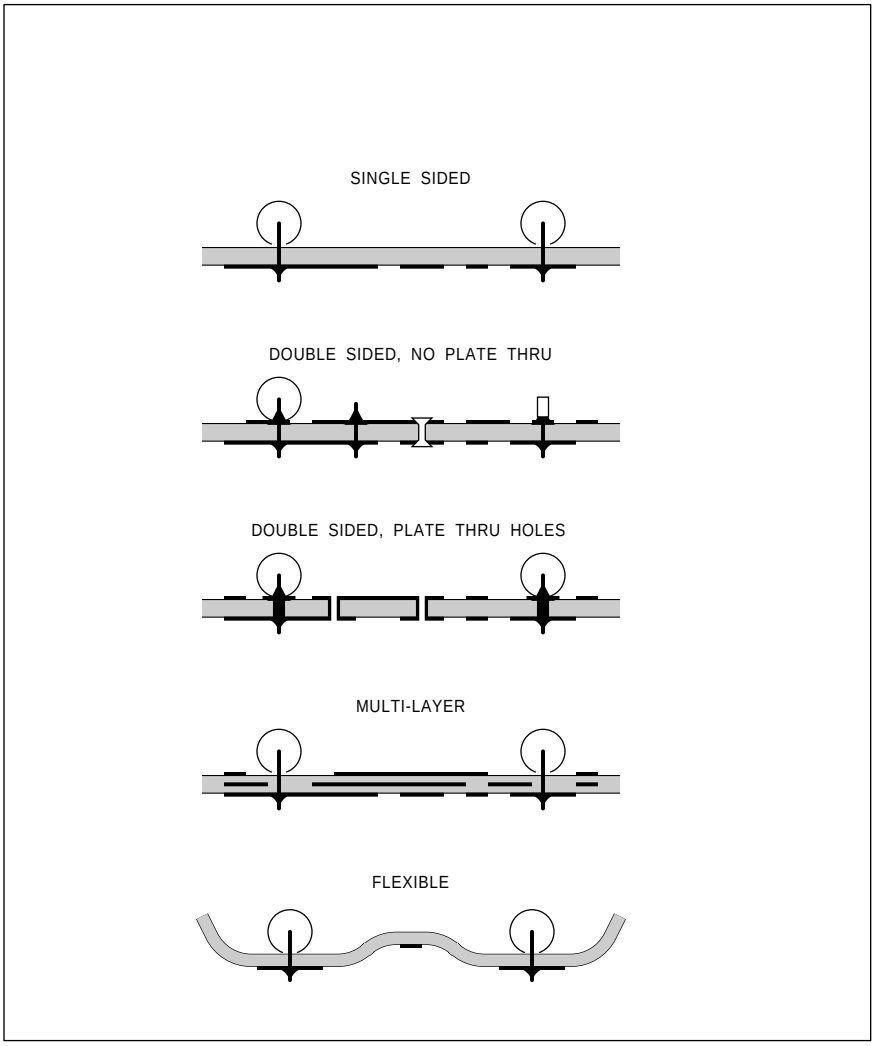


Fig. 1 – SEVERAL POPULAR TYPES of printed circuit boards. Note that a double sided plate thru board can be hacker faked by using component leads, eyelets, wire tabs, or low cost individual pin sockets.

mounted on the bare side of the board, giving us a *component side* and a *foil side* to work with. This allows a dip, a reflow, or wave soldering of all the parts at once. The components here tend to pull the foil towards the substrate, rather than trying to peel the foil from the board.

Single sided boards limit both your minimum size and how much you can connect where, unless you go to an unacceptable number of the interconnecting jumpers. Because of this, most modern boards are *double sided*, and have foil on both surfaces. While the most common means of routing connections between the two board sides is with *plated through holes*, hacker alternatives are eyelets, wire tabs, the component leads by themselves, or individual socket pins. *Mill-Max* is a leading source of low cost socket pins, and *Stimpson* is a good eyelet source.

A double sided plate through setup is beyond what most hackers would care to attempt. The tanks and such alone can set you back the better part of $10,000.00. Nasty chemicals are involved that are hard to get in small quantities. Worse yet, it takes a long time and involves several dozen steps, all of which have to function perfectly to ever get any product out the far end. You could farm out a lot of prototype boards at $30 to $60 before you could ever justify this investment.

Fortunately, the latest of the *surface mount* technology components tend to greatly minimize both the number of holes and the need for plate thru. So jumpers, eyelets, or individual socket pins are not really all that bad an alternative for your prototype boards.

The next step beyond double layer boards are *multi-layer* boards, where circuitry is placed *inside* the substrate, as well as on both surfaces. Typically, there will be four layers. Your horizontal runs will dominate on the top surface, followed by a lower power supply plane, a ground plane that is lower still, and the vertical runs that dominate the bottom surface.

As you might guess, all four layer boards are quite expensive and are extremely hard to modify, but they do offer superior shielding and extreme component densities. Multi-layer pc boards as dense as 24 layers have been built. Quite often, the multi-layer pc board will be the most expensive part of an electronic system.

Flexible boards are also becoming popular. These are often thinner and use a *Kapton* substrate. Uses include mounting connectors, and for highly dense or unusual packaging. *Rogers Corp* is a leading source of flexible pc board supplies.

1. Always do your layouts double sized (2X) on a blue gridded mylar sheet, available from any drafting supply house. Always work on a light box. Use only "real" printed circuit tape and dots. *Bishop Graphics* is one source.
2. Watch which side you tape from. Pin one of an integrated circuit is at the *lower left* when viewed from the top as shown in the data book. Pin one will be at the *lower right* when etched from the bottom board foil.
3. Never cut your tape with an X-acto knife! Instead, lay the knife down flat and pull the free end of the tape back against the blade. Always firmly mash the tape in place after routing. A teaspoon is ideal for this.
4. Never do your own photography! A litho negative costs only $3 at a jiffy printer, ad agency, or lithographers. This is the *only way* to get the proper precision and density.
4. Never coat your own boards! Always use commercially precoated dry film boards, such as those from *Kepro*.
5. Always use dry film photoresist, rather than spray-on or liquid coated KPR types. Otherwise, pinholes, dust, and uniformity will eat you alive.
6. If you must coat your own board, incredible cleanliness is essential. Thoroughyly scour the board with ultra fine steel wool and a chlorine activated (*Comet*) cleanser at least three times, spending not less than two minutes per square inch of board. Dry promptly and avoid all finger prints. If possible, follow up with a chemical copper cleaner. Then etch for a few seconds, rinse four times, dry, and use immediately.
7. Note that properly cleaned copper will allow an unbroken film of water to flow over it, and that it will *not* be copper colored at all. Instead, it will be a uniform hot pink.
8. Never print through the negative base! Always have the photo emulsion in direct contact with the dry film photoresist.
9. Never use a ferric chloride etchant! Always use ammonium persulfate.
10. Always etch at an elevated temperature, around 120 degrees Farenheit. A warming plate from a yard sale is ideal for this. Agitate the etchant with a gentle sloshing or bubbles from an aquarium pump.
11. Never etch with your foil side up!. Support the board vertically, or else *foil side down* at least 1/2 inch above the bottom of the etchant tray. A mirror *under* a glass etchant tray lets you view etching progress. Use only plastic or glass in contact with your etchant.

Fig. 2 – SOME REALLY DUMB MISTAKES are often made by hackers who do their own printed circuit boards the "old way". Here is how to avoid the worst of the pitfalls of the traditional methods.

Creating a Printed Circuit

There's a number of good ways to create a final printed circuit board. In general, those methods that put new conductors on an insulating substrate are *additive*; those that can remove unwanted conductors from unneeded areas are *subtractive*. Very often, both additive and subtractive techniques will be used in combination.

Four of the traditional board production techniques include the *direct*, the *mechanical*, the *silk screen*, and the *photographic*.

In the direct board method, an etch-resisting pattern is applied by hand to the printed circuit stock. Most any paint, lacquer, instant transfer, or ink will work, as will the tape and dots intended for initial layout work. So does a fingerprint or spilled root beer. *Bishop Graphics* is a leading supplier of pc tape and dots, and *Datak* is one source of the instant transfer products. There are also some rubber stamping

PRINTED CIRCUIT RESOURCES

Advance Process Supply
400 North Noble Street
Chicago, IL 60622
(312) 829-1400

Bishop Graphics
5210 Lewis Road
Agoura Hills, CA 91376
(818) 991-2600

Black Lightning
RR 1-87 Depot Road
Hartland, VT 05048
(802) 359-2790

Circuits Manufacturing
500 Howard Sreet
San Francisco, CA 94105
(415) 397-1881

Datak
3117 Paterson Plank Road
North Bergen, NJ 07047
(201) 863-7667

DuPont Riston
3945 Freedom Circle F4
Santa Clara, CA 95054
(408) 562 9300

Electronic Manufacturing
17730 W Peterson Road
Libertyville, IL 60048
(312) 362-8711

Electronic Packaging
1350 E Touhy Avenue
Des Plaines, IL 60018
(312) 635-8800

Kepro Circuit Systems
630 Axminister Drive
Fenton, MO 63026
(314) 343-1630

Kodak
343 State Street
Rochester, NY 14650
(716) 724-4000

Lazer Products
12741 E. Caley Ave. #130
Englewood, CO 80155
(303) 792-5277

Meadowlake
25 Blanchard Drive
Northport, NY 11768
(516) 757-3385

Miller-Stephenson
Box 950
Danbury, CT 06813
(203) 743-4447

Mill-Max
190 B Pine Hollow Road
Oyster Bay, NY 11771
(516) 922-6000

Rogers Corp
100 S. Roosevelt Avenue
Chandler, AZ 85226
(602) 961-1382

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

SignCraft
1938 Hill Avenue
Fort Myers, FL 33906
(813) 939-4644

Southern Sign Supply
127 Roesler Road
Glen Burnie, MD 21061
(301) 768-8600

Stimpson
900 Sylvan Avenue
Bayport, NY 11705
(516) 472-2000

Surface Mount Tech
17730 W. Peterson Road
Libertyville, IL 60048
(312) 362-8711

Synergetics
Box 809
Thatcher, AZ 85552
(520) 428-4073

Thiokol Dynachem
2631 Michelle Drive
Tustin, CA 92681
(714) 730-4200

Thompson & Thompson
23072 Lake Center #100
El Toro, CA 92630
(714) 855-3838

Ulano Corp
255 Butler Street
Brooklyn, NY 11217
(718) 622-5200

layout aides being offered. These are just about totally useless.

Actually, the direct method is more hassle than it is worth, and ends up just about totally useless. Some problems here are pattern alignment, preventing fingerprints, tape lifting, a lack of uniformity, and too many defects.

The mechanical methods physically remove unwanted copper, usually by routing, special drills or by milling. This is another concept which looks much better on paper than in the real world. Several specialized systems are usable for the mechanical pc layouts. Invariably, they are both laughingly and obscenely overpriced.

The silk screen pc method is quite simple and gets widely used commercially, especially for the single sided boards of fairly low tolerances. The process is exactly the same as silk screening a T-shirt or a greeting card. Oversize artwork is created, usually at a 2:1 or sometimes a 4:1 scale. A litho negative gets shot from this artwork, which in turn creates a photo master for the screen. High resolution screens are used, often in a 20XX density.

To print a board, etch resisting ink is placed on the screen, and a squeegee is used to force the ink through the open portions of the screen. The board is then etched to remove all copper that is *not* covered by the inked image.

The advantages of the silk screen

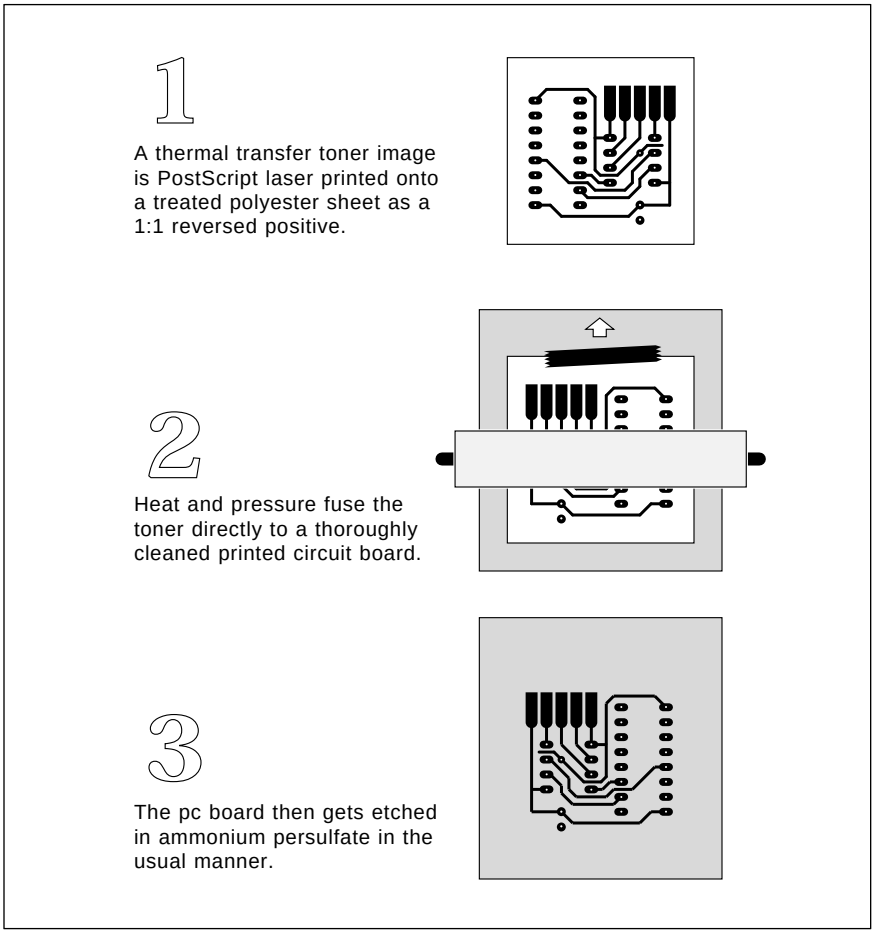


Fig. 3 – OUR NEW DIRECT TONER TRANSFER method can dramatically simplify and speed up making all of your hacker printed circuits at costs of only pennies per board. The process takes around twenty seconds.

method are that it is cheap, fast, and relatively low tech. One disadvantage is the $30 setup charge per screen does get out of hand when you only want a single prototype board. A second is the inability to do very fine lines or precisely aligned work.

Ulano is one major source of silk screen films. The screens themselves are available from such sources as *Dick Blick*, *Southern Sign Supply*, and *Advance Screen*. Two trade journals that serve this field are *Screen Printing* and *Signcraft* magazines.

At one time, printed circuit boards were etched by using a ferric chloride solution. Today, ferric chloride is a *very poor* choice of etchant. A much better etchant choice is ammonium persulfate. It is much cleaner, faster, and easier to use. Being a light blue in solution, ammonium persulfate also lets you view the board as it is being etched. Etching best takes place at an elevated temperature, typically 120 degrees F. You could easily hit this temperature with a modified aquarium heater, a warming plate from a yard sale, or any of the strip heaters found on the surplus market.

Everything that contacts the etchant must be glass or plastic. PVC is often a usable choice. Ideally, your etchant should be sprayed onto the vertically held boards. Other ways to keep the etchant moving would be a simple manual sloshing or injecting air from an aquarium pump.

1. Create a PostScript printed circuit artwork image on disk, using your favorite word processor and the sample routines of figure five and six, the full code found in my *PostScript Show and Tell*, or some suitable third party printed circuit layout package.
2. Run a positive, reversed 1:1 proof on a PostScript speaking laser printer, such as an *Apple LaserWriter IINT*. Many copy shops offer this service. Low cost PostScript printers are available through *Don Thompson*.
3. Optional step: Take a polyester based, laser printable overhead transparency material and lightly coat one side with *Miller-Stephenson* type MS-136 heated mold release agent. Mark the coated side.
4. PostScript laser print a 1:1 positive reversed (black = foil; right = left) onto the coated side of the polyester sheet, using a special thermal transfer (T-shirt) toner from *Black Lightning*, *Don Thompson*, or *Lazer Products*. Other graphic toners might also work; try them and see.
6. Sharpen and smooth the leading edge of an oversize piece of 1/16th inch printed circuit material with a file and steel wool , so that it can be sent through a fake *Kroy Kolor* machine without hurting the rollers. Use a 3/8 to 1/2 inch leading slope.
7. Thoroughly clean this oversize printed circuit board, scouring it three times with fine steel wool and *Comet* cleanser, followed by a chemical cleaner, followed by a brief etch. The board must be a uniform hot pink in color and must allow an unbroken stream of water to flow smoothly over it. Be sure to avoid any and all fingerprints.
8. Tape the leading edge of the polyester sheet *toner side down* to the copper side of the printed circuit board, using a suitable high temperature tape. Make sure the polyester sheet lies flat.
9. Run the board, image side up, through a preheated fake *Kroy Kolor* machine adjusted to a medium temperature. One source of these machines is *Lazer Products*. See the November 88 *Radio Electronics* or my *hardware Hacker II* reprints for details on building your own machine.
10. Optional step: Chill the board suddenly in a freezer before lifting the polyester sheet. Allow to warm to room temperature, then bake for fifteen seconds at 300 degrees F in a kitchen oven.
11. Etch in the usual manner in ammonium persulfate etchant.

Fig. 4 – THE STEP-BY-STEP "BASELINE" process for the new toner transfer pc method. An ordinary iron can be substituted for the Kroy Kolor machine, but the results may not end up as good. Let us know your experiences here.

One really dumb mistake that most hackers make when etching their first pc board is to place your board *face up* in the etchant solution. All this does is redeposit sediments and any crud removed from the board back on itself, leading to all sorts of nasty problems.

Instead, always support your boards vertically in the etchant, or else use surface tension to float your board *upside down* on the surface of the etchant. Another ploy is add nylon spacers to your pc board so the foil faces *down* in your etching solution. Or else throw some nylon hex nuts in the etchant and sit the board upside down on the nuts. Once again, *never etch a pc board face up!*

A second stupid mistake that lots of hackers make is failing to clean the boards properly. It is not possible to clean a circuit board at home without spending not less than *two minutes per square inch of board*. Begin by using *Comet* or another chlorine-activated cleanser with a fine steel wool pad or *Scotchbrite* pad. Rinse thoroughly and wipe on an inner fresh turn of a new roll of paper towels. Repeat this at least three times, avoiding any and all fingerprints.

Note that fairly clean copper will allow an unbroken stream of water to flow over it without any running or beading. Your key secret is that a genuinely and totally clean copper will not be copper colored at all. Instead, it will be a uniform hot pink.

Commercial copper cleaners, such as CU3 from *Kepro*, are a great help here, but are somewhat expensive.

The ultimate final cleanliness step is to place the copper in ammonium persulfate and etch it for ten to fifteen seconds or so. Then thoroughly rinse three times and air dry immediately. If you get a uniform hot pink result, then your copper is clean enough for your immediately use.

The photographic methods do get rather complicated, but they can be used for arbitrarily fine lines and for all of the precision you will ever need. In fact, the same techniques are used to manufacture integrated ciruits to a fraction of a micron accuracy. Note that there are 20 microns in a mil.

With the photo processes, a light sensitive *etch resist* is placed on the

thoroughly cleaned board. This resist is contact printed from a photographic negative and then is developed. In the most popular *negative acting* systems, the portions of the resist that receive light harden and remain; those that did not will dissolve out. Etching is then done in the usual manner.

Traditionally, the spray on photoresist was used, such as a KPR product from *Kodak*. These days, though, it is far simpler and far better to use a dry film photoresist, such as the *Riston* materials by *DuPont*, or any of the *Laminar AX* products from *Thiokol*. These dry films develop in trisodium phosphate, the garage floor cleaner found at your local hardware store. They are quite resistant to pinholes, eliminate dust and drying problems, have highly visible images, and are always at the right thickness.

Once sensitized, the boards must be kept dry, cool, and in total darkness. They also have a one year shelf life.

The third most stupid mistake that hackers make is trying to use KPR instead of the new and infinitely better dry films. Mistake number four, of course, is trying to coat all their own boards instead of using pre-coated ones. Excellent dry film pre-coated boards are stocked by *Kepro*.

The cost of the dry film resist by itself is around a dollar per square foot. Unfortunately, a fancy laminator is needed to bond the resist to the board. I have a hunch a Kroy Kolor machine or one of its imitators can be substituted here. The required temperature is 234 degrees Farenheit. Let me know if you pick up any experience along these lines.

Double sided, plate-through boards often use a combination of processes. Typically, you start with a double sided board. The holes are first drilled, and then they are plated through by additive techniques. The holes get chemically activated, and then seeded with an ultra-thin palladium plating. Electroless copper is then built up on the conductive palladium to a medium thickness, followed by a heavy copper plating up to the final wall thickness needed. The rest of the board is then processed through the usual double-sided photographic steps.

Key hacker printed circuit mistakes are summarized for you in figure two. Be sure to avoid them.

Printed Circuit Resources

I've gathered some of the major pc board resources into our first sidebar, as we've done in previous columns for other topics. Most of the products we have mentioned are available directly through these sources.

The greatest hacker source for any and all pc goodies is unquestionably *Kepro*, who have everything from bare and dry film boards stock up through complete plate-thru labs. Yes, they are a tad on the pricey side. Until you add in the "Uh – compared to who?" and the convenience factors.

The best trade journal for printed circuits is *Circuits Manufacturing*. A few others are *Electronic Packaging and Production*, *Surface Mount Technology*, and their sister publication, *Electronic Manufacturing*.

Be sure to let me know if there are other resources you think should be added to this list.

The Direct Toner Method

There's a new process on the block for hacker printed circuits which is ridiculously simpler, faster, and far cheaper than any of the above. All you really need is a word processor and an iron. This new scheme is known as the *direct toner method*. And it is new enough and undeveloped enough that you can play a major role in making it work and shaping its future.

Very simply, copier or laser printer

```
%  Copyright c 1988 by Don Lancaster & Synergetics, Box 809, Thatcher AZ, 85552.
%  (602) 428-4073. All rights reserved. Personal, non-commercial use permitted so long
%  as this header remains both present and intact. Show & Tell disk costs $39.50.

/quadpixel {transform 4 div round 4 mul itransform} def

/setgrid {save  /rubbersnap exch def /size exch def quadpixel exch quadpixel exch translate
size dup scale } def

/drawlines {72 300 div lw mul size div setlinewidth /hposs 0 def #hlines gs div 1 add cvi
{hposs 0 moveto 0 #vlines rlineto stroke /hposs hposs gs add def} repeat /vposs 0 def
#vlines gs div 1 add cvi {0 vposs moveto #hlines 0 rlineto stroke /vposs vposs gs add
def} repeat} def

/showgrid{gsave /#vlines exch def /#hlines exch def 106 45 {pop pop 0} setscreen 0.9
setgray /gs 1 def /lw 1 def drawlines  grestore} def

/1X {30 72 mul 300 div setgrid} def

/trace20 {6 30 div setlinewidth} def /trace50 {16 30 div setlinewidth} def /trace80 {24
30 div setlinewidth} def

/am {newpath moveto} def
/tdraw {rlineto currentpoint stroke moveto} def

/u {0 exch tdraw} def          /r+ {dup tdraw} def
/r {0 tdraw} def               /r- {dup neg tdraw} def
/d {0 exch neg tdraw} def      /l- {neg dup tdraw} def
/l {neg 0 tdraw} def           /l+ {dup neg exch tdraw} def

/black {0 setgray} def         /white {1 setgray} def

/xrpt{gsave aload pop /trips exch def /dist exch def /rproc exch def trips { gsave rproc
grestore dist 0 translate } repeat grestore} def

/yrpt{gsave aload pop /trips exch def /dist exch def /rproc exch def trips { gsave
rproc grestore 0 dist translate } repeat grestore} def

/hole {gsave 150 div /dia exch def newpath dia 2 div 0 360 arc white fill grestore} def

/icpad1v {save /psnap exch def trace50 2 copy gsave exch 0.2 sub exch am 0.4 r grestore
20 hole psnap restore} def

/edgeconu {gsave translate 0.4 0 moveto 0 -2 0.4 0 180 arcn 0 2 rlineto closepath fill
grestore} def

/feedpad {save /fpsnap exch def newpath 2 copy black 0.25 0 360 arc fill 18 hole clear
fpsnap restore } def

/circpad2 {save /fpsnap exch def newpath 2 copy black 0.30 0 360 arc fill 22 hole clear
fpsnap restore } def

/dip8v{gsave translate [{0 0 icpad1v} 1 4] yrpt [{3 0 icpad1v} 1 4] yrpt grestore} def

/dip16v{gsave translate [{0 0 icpad1v} 1 8] yrpt [{3 0 icpad1v} 1 8] yrpt grestore} def

1 setlinejoin 1 setlinecap
```

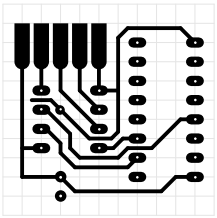
Fig. 5 – SAMPLE POSTSCRIPT PC LAYOUT routines that were excerpted from my PostScript Show & Tell disk. Just shove this listing into your favorite word processor as a prolog to your actual layout.

toner is outstanding as an etch resist. Two decades ago, *Xerox* even had a product that directly printed on your copper pc boards from a 2:1 artwork original. A ways back, a new hacker product known as *Meadowlake* did attempt an iron-on toner system. Early versions of the product didn't turn out reliable enough and lacked stability.

But there is a brand new type of *thermal transfer toner* now carried by several of those laser printer supply houses. While this toner is intended for making iron-on T-shirt images, it transfers to copper beautifully and smudge free, and is thus a key secret to the direct toner process. Three sources of a thermal transfer toner are *Black Lightning*, *Lazer Products*, and *Don Thompson*. Black lightning does offer a free sample. Cost of the toner ranges from $90 to $180 per cartridge, which translates to a dime per board.

Several of the other new graphics toners should also work well. Your help is needed in pinning down which ones are acceptable and which are not.

Figure three summarizes the key toner transfer steps, followed by some detailed instructions in figure four.



```
% uses figure five code

100 100 1X 11 11 showgrid
trace20 10 2 am 1 l 0.75 l- 4.5 l
0.75 l+ 2 l 6 u 10 5 am 0.75 l 1.5
l- 1.25 l 0.5 l- 2 l 0.5 l+ 0.75 u
1.25 l+ 7 4 am 0.75 l  0.5 l- 0.75
l 5 5.5 am 1 l+ 1.5 u 5 4.5 am 2
l+ 2 u 2 6.5 am 1.5 u 7 3 am 0.5
l- 2.75 l 0.75 l+ 0.5 u 0.75 l+ 2
3.5 am 1 l 10 9 am 0.75 l+ 2.75 l
0.5 l- 2.75 d 1 l 6 6.5 am 2.15 d
0.35 l- 1.15 l 2 l+ 1 l 5 6.5 am
1.5 u 7 2 dip16v 2 3.5 dip8v [{1
10 edgeconu} 1 5] xrpt 3 2
circpad2 3 1 circpad2 3 5.5
feedpad showpage quit
```

Fig. 6 – TYPICAL PC LAYOUT. Omit the *showgrid* command to delete the fine gray viewing grid.

The best way I've found to create initial artwork is by using a PostScript speaking laser printer and my word processor. In fact, I have a complete package that does just this for Apple, Mac, and IBM users. Note that the original image must be a 1:1 *reversed positive*. This means that left is where right belongs but black is where you want your foil to *remain*. Naturally, since your image is disk based, it is easy to change, and super easy to build up from a library of suitable PostScript dictionary routines.

The image gets printed, again as a 1:1 reversed positive on to a laser printable mylar or polyester overhead projection sheet. Just for luck, I'll previously apply a very thin coating of MS-136 *Heated Mold Release Agent* from *Miller-Stephenson*. This may or may not help, but it sure seems like a good idea, at least for now.

It also may be a good idea to anneal or remelt the toner for a few seconds in an oven, after the image is transferred. Too much reheating, of course, would lower the resolution.

Speaking of which, although ten mil lines on twenty mil centers should be possible, I'd stick with double this as an initial lower limit.

In theory, you could simply iron the toner directly onto a previously super-cleaned pc board. Instead, I modify the board by *sharpening* its leading edge, and run it through one of the imitation *Kroy Kolor* machines we looked at in a previous issue. By the way, an improved and economical do-it-yourself version of this beast is in the works here at **Radio-Electronics**. Hopefully, it should be able to Kroy Kolor, laminate, transfer toner to pc boards, apply dry film photoresist, and possibly even hot stamp.

The benefits of this new way are obvious. You go from artwork to pc prototype amazingly fast. No cameras, chemistry, screens, or fancy equipment is needed. Without any fuss or bother. Just print and etch.

And products such as *GoScript* and *Freedom of the Press* even let you fake PostScript on a dot matrix printer, so no printer is no excuse.

This could also revolutionize running hacker pc projects. You show the PostScript code in the magazine and offer it downloadable off your BBS. Now, every hacker can end up with a precisely accurate original, rather than a third generation copy.

Figure five shows you some sample PostScript code from my pc layout stuff, while figure six shows you a simple actual layout you can use to test out your own version of the direct toner board method.

New Tech Literature

The hacker buy of the month has to be the new $3.75 speech synthesizer available as stock number ICA from *All Electronics*. It even includes a load power sensing detector. There is one very tiny gotcha, though – the main thing the synthesizer has to say is "Your ice cream is ready". Oh well.

The *EG&G Reticon* folks have three brand new data books out. These are their *Image Sensing Products*, *Solid State Cameras* and their *Analog Signal Processing Integrated Circuits*. The latter covers analog delay lines, switched capacitor filters, and some very useful ap-notes.

The BU2911 is an interesting new melody chip from *Rohm*. It provides a pair of folk songs and six different chime and siren sound effects. Uses? How about some clocks, doorbells, or alarms for a few starters.

Miniature fluorescent lamps from *JKL* are offered in various colors at very low prices; they also do carry EPROM erasing lamps.

The *SPIE* folks have great heaping bunches of reprints involving nearly everything optical, and covers laser scanning, CD ROM, holography, fiber optics, and infrared detection. Get their list number 6.

Turning to mechanical stuff, free molded gear samples are obtainable from *Winzeler*. And *Robert A Main* has a unique catalog of *Hooks, Points, and Teeth*. A sharp outfit fer sure.

If you do want to explore our new direct toner hacker pc process further, or want to draw your own first quality electronic schematic diagrams, any isometric drawings, or architectural perspective sketches (even including all lettering!) using nothing but your favorite word processor, check into my *PostScript Show and Tell*, that has scads of working code and detailed examples in it. Available for Apple, Mac, or IBM, it does need a PostScript speaking laser printer or a software emulator for your final output. ✦

Keyword Index

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