Don Lancaster's

Hardware Hacker

Selected reprints — volume IV
Electronics Now series (January 1992 - January 1994)

Introduction

Welcome to the fourth volume in our ongoing series of my *Hardware Hacker* reprints from *Electronics Now* magazine. This volume includes the January 1992 through January 1994 columns.

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

I've tried to expand the topics beyond the strict boundaries of traditional electronics. Going into the science and math subjects many of you have asked for over our voice helpline.

I still get lots of pseudoscience and "free energy" questions. So, focus areas of this volume include thermodynamics, power transfer theorems, and related engineering fundamentals. Stuff that outright precudes *all* perpetual motion scams. At the same time, I have indexed and listed most of the fake pseudoscience sources. Mostly, because they make wondrously bizarre reading, I guess.

Some of the more popular subjects in this volume include distant FM reception, Newtek's *Video Toaster*, advanced halftone imaging, and new solar energy developments. Plus updates on wavelets, caller ID, and GPS navigation. And great stuff on cubic splines, UFO's, and phone interfaces.

Preprints and reprints of most of my columns are also available electronically via *GEnie* PSRT. Presented in both *PostScript* and *Adobe Acrobat* formats. For *GEnie* access, have your modem dial (800) 638-8369. After the prompt, enter JOINGENIE. When you are later asked for your keycode, enter DMD524.

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

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

About the Author

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

Microcomputer pioneer and guru Don Lancaster is the author of 33 books, 2 videos, and countless articles. These include his *TTL Cookbook* and *CMOS Cookbook* internationally published million seller classics. Don is considered by some to be the father of the personal computer, for his early ground-breaking work with hacker digital electronics and low cost video terminal displays. He is considered by others to be the patron saint of the Walter Mitties of the World. And by yet others as the… Uh, I guess we better skip that one.

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

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

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

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Hardware Hacker

January, 1992

Wavelets. We have got lots of wavelets. You getcher wavelets here. As we've discovered a number of times before, wavelets are a stunning new math concept that is profoundly changing virtually all the advanced electronic topics. A failure to learn wavelets *now* is the same as volunteering for early retirement.

We've already seen that *Jones and Bartlett* has published THE great new wavelets book, and that the *Ultrawave Explorer* from the *Aware* folks is one fine commercial wavelet study and development program.

But the big news is that I've just posted full working PC shareware copies of the *Wavelet Packet Library* from *Digital Diagnostics* on *GEnie* PSRT as #365 WAVELET.PS.

Those of you into satellite dishes and microwave electronics are now probably familiar with *Smith Charts*, a handy graphical method of doing things like impedance matching and tuning. I have written a PostScript Smith Chart generator that lets you instantly create all your own Smith charts in any quantity, any size, any resolution, and any where in your publication. Check *GEnie* PSRT #367 SMITHCHT.PS for several freeware samples. Your downloading cost on this is around twenty one cents.

Perpetual Motion Again

I get an average of three to five helpline calls a week on "free energy" and other perpetual motion topics. As we have seen in the past, perpetual motion is definitely real as a historic and ongoing societal phenomenon. We have also seen that two ongoing sources of perpetual motion books, videos, and papers are *High Energy Research* and *Lindsay Publications*.

Now, I personally feel that looking for any free energy systems is rather dumb. First, because the desirability of any free energy ranks somewhere between Herpes and AIDS. Why? Because this would obviously hasten the already ongoing entropic heat death of the planet. If someone does in fact

find a free energy system, they should be spanked and sent to bed without any supper. Or, better yet, chopped up and fed to the cows.

Second, because the odds of your accomplishing anything that's even remotely useful involving free energy are stupendously low. Third, because your credibility starts out as less than zero and quickly plummets. Owing to previous scams, the "not even wrong" research, and the "few-chips-shy-of-a-full-board" guilt by association.

And, finally, because there's so much better to be doing. We're sitting on the greatest mountain of new hardware hacking chips, tools, info, and concepts anywhere ever. Stuff that's crying for hacker use, and stuff that is nearly certain to result in lots of interesting and profitable things. Why ignore the obvious?

Several of the recent callers were making measurements that were just plain wrong. Since I am one of the world's foremost experts in gathering incorrect, misleading, or meaningless lab data, I thought we might briefly focus on a few of the ways that casual measurements may not end up what they appear to be.

In general, you'll *always* want to assume that *all* meter pointers and, especially, *all* of your digital numeric displays are lying through their teeth. Or, if they are giving you a correct reading, the odds are overwhelming that the *meaning* and the underlying *reasons* for that reading are not at all what you had in mind.

Oscilloscopes do a far better job than the meters or digital displays at showing you what is really coming down. Even here, an uncompensated probe, the wrong setting, improper sync, an invisible glitch, any outband signals, or just a ground clip that is slightly too long can cause you wildly incorrect results.

It is only when the same tests are run over and over again by different people under different circumstances that you can even remotely begin to trust your instruments. Even when repeated, that trust should only apply to the *exact* measuring conditions.

A ferinstance. Figure one shows you a seemingly simple method to measure ac power. You connect your new motors-and-magnets perpetual motion machine load to the ac power line through an ammeter and then separately measure the line voltage. Since power equals volts times amps, you just multiply your two readings together and you'll have the input power. Right?

Wrong. Dead wrong.

Let's temporarily forget about any noise, spikes, back-EMF effects, harmonics, and nonlinearities that are certain to be present with your new motors-and-magnets load. Assume a pure sinewave voltage and a similar current waveform. You have to take the *phase* of the current into account. You would get a zero phase shift with a purely resistive load. In a purely inductive load the voltage would *lead* the current by 90 degrees. In a purely
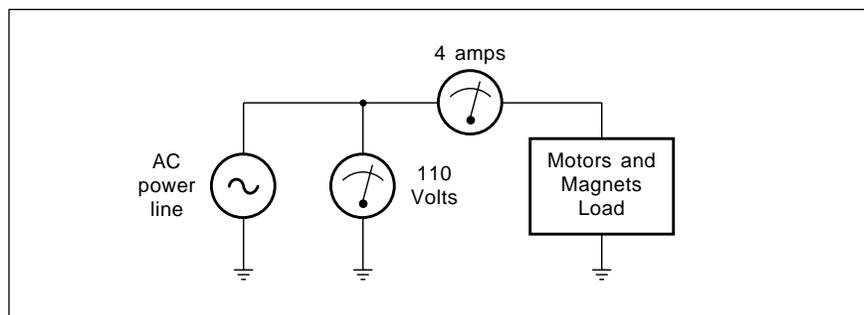

Fig. 1 – WHAT IS THE REAL POWER being consumed in this test circuit? There's no way to tell with the setup shown. But you can safely bet that it is probably not anywhere near 440 watts.
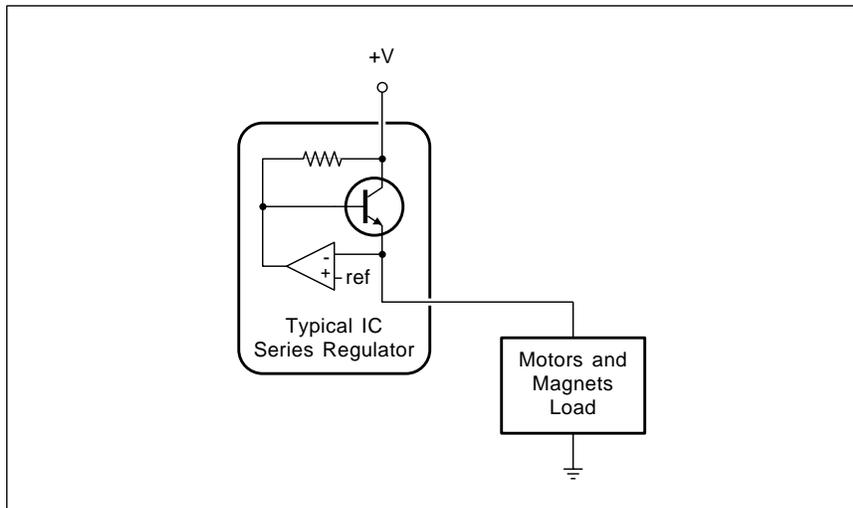
Fig. 2 – WHEN IS A REGULATOR NOT A REGULATOR? Any time that your load tries to source (rather than sink) power, a typical IC voltage regulator will shut down or else become unstable. There is no current path to ground.

capacitive load, the voltage will *lag* the current by 90 degrees.

Good old *ELI THE ICE MAN*. The voltage is ahead of the current in the eLi's L inductor; the current is ahead of the voltage in his iCe capacitor.

And if you have any purely active load such as another generator, your current could end up phased by 180 degrees. Sourcing, not sinking.

Your actual power will end up the voltage times the current times the cosine of the phase angle between the two. If your voltmeter reads 110 and your ammeter reads 4, your actual circuit power will be 440 watts to a purely resistive load, ZERO to any purely inductive or capacitive load, and MINUS 440 watts to any purely active load. Or anything between, depending upon your phase angle.

Why is the power zero to a purely inductive load? Because of the phase angle. A math freak will tell you the full cycle cross product of a sine and its cosine is zero. Intuitively, on the first quarter cycle, you have positive voltage and current. On your next quarter cycle, you will have positive voltage and negative current. On the next, negative voltage and negative current. And finally, negative voltage and positive current. Add them all up and average them all out and you end up with zero real power.

Yes, you will get lots of back-and-forth reactive power that can give you real fits. And hack off your electric utility. But your net real power into a pure inductive or capacitive load is precisely zero.

Thus, as far as power goes, all the voltmeter and ammeter readings are *totally meaningless*. And even less so in the presence of noise, back EMF's, sparking, or harmonics.

Measuring Real Power

So how do you measure real and reactive power? The trick is that you have to multiply the *instantaneous* voltage and current together. Then you sum to find the total power.

The power of any arbitrary waveform is equal to the DC continuous power that would give you exactly the same amount of total heating in a purely resistive load.

You can do this measurement with a real *wattmeter*, or by measuring the rotational speed and direction of a *watthour meter*. The wattmeters and watt-hour meters are often available through *Fair Radio Sales* or *Herbach and Rademan*.

Electronically, you can use a multiplier chip or a special RMS power calculating circuit. *Analog Devices* is one leader in low cost power chips of this type.

Or graphically, you can take plots of all the exact voltage and current waveforms, split them up into time slices so narrow that the voltage or current does not change much, multiply the results of those slices and then sum the results.

Note that you *must* multiply first and then add. Never vice versa.

But you still do have to be careful. Nonlinearities, pulses, harmonics, motor back EMF effects and noise require special treatment. And most power measurement schemes have a *crest factor* limit which ruins their accuracy on strong but narrow pulses. Especially spikes and glitches.

For these reasons, it is extremely difficult to accurately measure your input power to a motors-and-magnets perpetual motion machine. If you do not know *exactly* what you are doing, all your results are *guaranteed* to be wildly wrong. And so, of course, will be your conclusions.

Figure two shows you a second measurement pitfall that the recent callers have all decided to ignore. A voltage regulator is always a voltage regulator, right?

Wrong. Dead wrong.

Most popular voltage regulators are only capable of *sourcing* current. If the *load* starts *sourcing* any power even briefly, there is no place for the current to go, and the regulator either shuts down or starts oscillating.

Thus, if you have a motors-and-magnets load, there could be times when the back EMF effects, spikes, commutator noise or whatever, will try to *source* power back *into* your supposed power source.
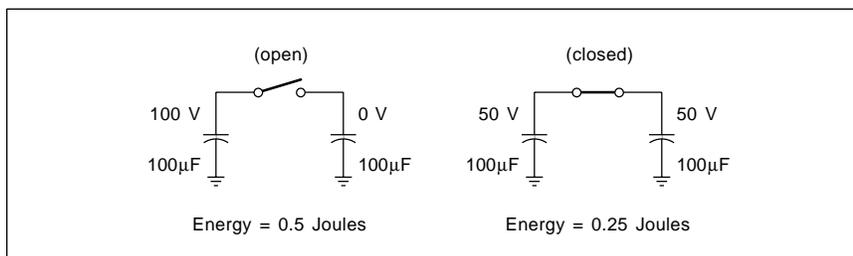

Fig. 3 – QUICKLY CLOSE THE PERFECT and lossless switch. And half of your circuit energy will vanish without a trace. Where did the energy go?

Put in another way, typical power supplies and most regulators have wildly different impedances between when they source and sink power.

Note that any normally connected Zener diode will behave precisely the opposite – they are great power sinks but poor sources.

An output filter capacitor on your regulator is essential for grabbing and smoothing out high frequency load sourcing variations.

Beyond proper output filtering, two ways around load sourcing effects are to hang enough of a resistive load on your regulator that the regulator will always output a net sourcing current. Most batteries are usually capable of sourcing and sinking any reasonable amount of current.

Figure three shows you yet another way to go astray. All bets are off if there is any sparking or arcing. It is physically impossible to instantly change the voltage across a circuit capacitor or the current through an inductor. The usual result when you try this is sparking or arcing.

Take a 100 microfarad capacitor and charge it on up to 100 volts. Your energy in any capacitor is…

$$E = 0.5\,C\,V^2$$

or, in this case, 0.5 Joules of stored energy. Now, you close your lossless switch so you have two capacitors in parallel. The voltage must, of course, drop in half, since the same charge is now spread across twice your plate area. And by the same formula, you now have only 0.25 Joules of stored energy.

Question: Where did the rest of your energy go?

If you have a non-lossless switch of resistance R, the answer is easy. In the process of charging the second capacitor, the extra energy got burned up in your resistor as heat during charging. But go through the charging math, and you'll find that the loss of half the stored energy is a constant which is *totally independent* of the value of R!

If R equals zero, then you have to get a spark and radiated energy. But you still lose half of it, regardless of how good the switch is.

Thus, if there is any sparking or arcing whatsoever in your motors-and-magnets machine, your readings

are once again *absolutely certain* to be wrong.

Always think carefully about your measurements and how they could be wrong or misleading.

Lumeloid and Lepcon Films

We sure had a bunch of helpline calls over the new materials stuff I announced a column or two back and in our *Hardware Hacker III* reprints. I've picked up some more info, and have summarized where to go for more in our *Lumeloid and Lepcon Solar Resources* sidebar.

Let's start off with the bottom line: Yes, this looks like it someday could be real. Maybe. At least in the lab. No, you cannot yet buy the stuff by the yard through your local *K-Mart* fabric department and staple it to your roof. Yes, this is a great topic for a school paper or a science fair. And an incredible emerging research area.

On the other hand, *working prototypes do not yet exist*. And there are just enough "penny stock" and "media hype" aspects to all this that I have lowered my rating from "solar breakthrough" to "an interesting potential solar development." But you could judge for yourself, just by picking up on the resources in our sidebar.

The key individual behind all this is one Alvin Marks and his company of *Advanced Research Development*. Their OTC pink sheet stock is traded under the name *Phototherm*. This is strictly an unregistered blue sky security, and trading remains illegal in Massachussets, the issuing state.

Marks is a credible, experienced, and independent researcher with a long history of successful energy,

optical film, and pollution control developments. Among other things, he developed the cheap glasses once used for 3-D movies.

And EPRI, that ultra-conservative *Electric Power Research Institute* electric utility consortium has seen fit to fund Marks with a modest research grant. Albeit a paltry one by EPRI standards. Coffee money.

The two key patents involved are #4,445,050 *Device for Conversion of Light Power into Electric Power*, and #4,574,161 *An Ordered Dipolar Light-Electric Power Converter.*

There is very little published to date. And *all* of it is single sourced. None appears to be peer reviewed or critiqued. A collection of reprints is now available free on request from Advanced Research Development. One original paper has shown up as *Lumeloid Solar Plastic Films and Lepcon Submicron Dipolar Antennae on Glass*, from the 1990 *International New Energy Technology* symposium published by the *Planetary Association for Clean Energy*, located in Ottowa, Canada.

As we've seen a number of times in the past, you can quickly research any technical topic by using the *Dialog Information Service* at your local library, and then can get any reprint by using either interlibrary loan or the *UMI* reprint service.

So what is the big deal here and how does it work? Your traditional methods of generating electricity from the sun are seriously flawed. The old mirrors-and-boilers method involves a thermodynamic cycle with a *Carnot* thermodynamic efficiency limit around 35 percent. Besides not

The transformer is 1:1 600 Ohms, with a 1500 volt breakdown rating.

The zener diodes are 3.9 volt devices, such as a type 1N5228.

phone line

10 Ω

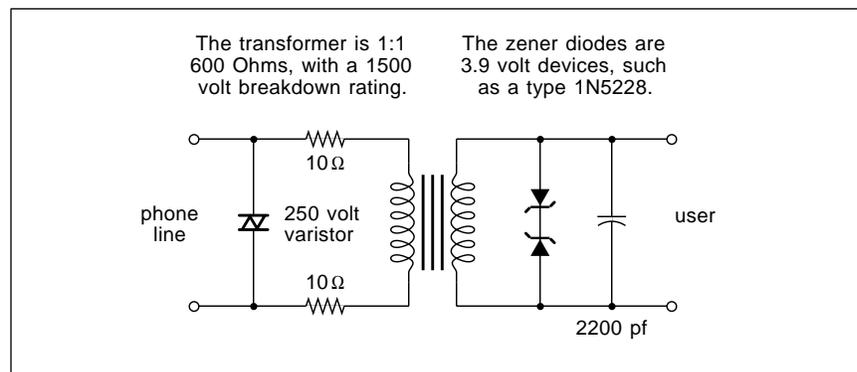250 volt varistor

10 Ω

user

2200 pf

Fig. 4 – A FCC PART 68 INTERFACE is required any time you connect any circuit of your own to the phone line. While this interface can be both simple and cheap, the required submission and approval process is not.

downsizing very well. Silicon solar cells at a theoretical 26 percent are even less efficient. It seems that they can only accept "whole lumps" of quantum energy, and have to throw the rest away as heat. And, before Marks, any photosynthesis scheme was well under six percent efficient.

And efficiency is everything in solar power. On a good day, you have one incoming kilowatt per square meter to work with. Say a nickel an hour "avoided cost" income for a perfect conversion. Or two cents a day allowing for night and weather. Naturally, your bottom line efficiency will usually be much less than your theoretical. Let your efficiency drop too low and there's no way that solar can be competitive. Get under the bottom-line efficiency of seven percent or so, and you will *never* be able to pay for your installation and land, owing to the time value of money. The longer it runs, the more it costs you for the financing.

But, alternatively, the nickel-per-kilowatt-hour incoming solar energy on a 2200 square foot house roof adds up to over $3000 a year. Which is lots more than usually gets used underneath as electricity. So efficient solar electric conversion could completely blow away coal, nuclear, and even most hydro.

Marks has developed two different solar to electric systems that seem to have high theoretical efficiencies.

Radio waves are electromagnetic. Solar energy is electromagnetic. The main difference between orange light (at 600 nanometers) and television channel two (6 meters) is a 10,000:1 size factor. Those light wavelengths may seem tiny, but we are starting to routinely handle *submicron* distances in integrated circuit manufacturing.

There's this thing called a *cyrstal set* that you might have heard of. Just shove some electromagnetic energy into an antenna, rectify it somehow, and out comes dc power. These days, we call the same thing a *rectenna*. So why not use light waves instead of radio waves?

An antenna is any subsystem for converting radiated electromagnetic energy into conducted wire electromagnetic energy. Or vice versa. As a transmitter, if your antenna is now properly *matched* to the rest of your circuit, nearly all of your input energy will get radiated. And, since most antennas are linear and reciprocal devices, if you input any electromagnetic energy well inside of the antenna's *effective area*, nearly all of it will get converted into conducted electricity. So, a properly matched antenna can be 100 percent efficient. And a rectifier nearly so.

Now, an optical antenna is trivial.

Just make it any old color so long as it is black. Even a black felt tip pen will do. The trick lies in rectifying and gathering all the received solar electromagnetic electricity, rather than burning it up as heat.

The *Lepcon* panel is the older of Marks' two new developments. In a Lepcon panel, tiny rectenna elements are created on glass using more or less conventional but very advanced microlithography. These are basically a conductive channel ending with a metal barrier diode. The photons in the incoming solar energy are used to accelerate electrons, which jump the barrier diode to become a dc current. Unlike a traditional solar cell, there are no "whole lumps only" quantum effects involved, and nearly all of the available energy gets converted.

The antenna/rectifier combination only works with one polarization of light. It converts the one polarization with up to a theoretical 80 percent efficiency, and passes the remainder on through. You could put a second Lumeloid panel underneath that is oriented 90 degrees from the first to convert the other polarization.

Or, you could use a sneaky trick consisting of a *quarter wave plate* and a mirror to rotate your rejected polarization by 90 degrees and shove it back *up* through the original film. Your combined efficiency ends up around a theoretical 72 percent.

The projected costs of the Lepcon process is around $250 per panel, and the panels should last 25 years.

The *Lumeloid* film process uses chemicals instead of very expensive microlithography. The chemical techniques in theory lend themselves to low cost and high volume production. The chemicals attempt to mimic the first half of the long photosynthesis process. A rather long chain carbon molecule, such as polyacetylene, is attached to some electron donor-acceptor complex, such as porphyrin and quinone.

The long chain molecule acts as a conductive antenna, changing the input optical energy into electron energy. The tunneling gap effect between the large donor and small acceptor rings acts as a rectifying diode for DC conversion.

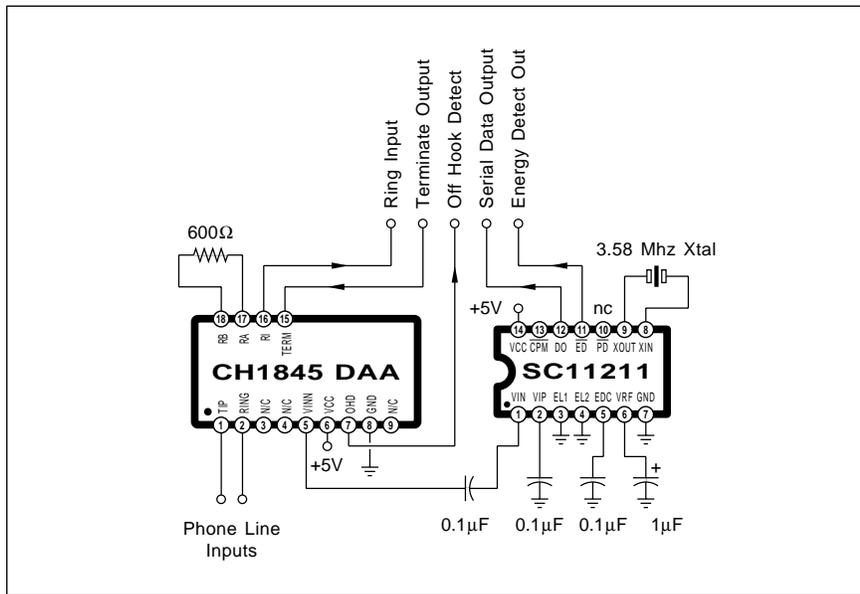For all this to work, the molecules have to be carefully oriented while

Fig. 5 – PRE-APPROVED PART 68 INTERFACE HYBRIDS are available, but they are rather expensive. Here is a caller ID circuit that uses the Cermetek CH1845 DAA interface and the Sierra SC11211 caller ID chip.

the sheet is being created. Mark's work has centered on suitable bulk processes to do the orientation in a low cost and high volume process. Projected costs are five dollars per meter and three cents per watt.

At present, the Lumeloid films are only expected to last a year in strong sunlight. Once again, Lepcon panels use conventional microlithography on glass, while Lumeloid use oriented films that mimic photosynthesis.

Interesting, the Lumeloid process is totally reversible. You can input electricity and get light out as well. Which could lead to new lighting and display technologies.

For any of this to become real, we will need working prototype panels, credible third party research, and the proper peer review. My "usual suspects" of *Science*, *Nature*, *Science News*, and the technology page of the *Wall Street Journal* have been suspiciously silent to date.

My own feelings are that short and open circuits in production panels are going to lead to the very same type of yield problems that have held back and restricted development of large area flat panel tv displays.

Because of the lack of even lab prototypes, their efficiency and cost projections at this time would appear totally meaningless. Although having a high theoretical efficiency sure does help. But time will tell.

Caller ID Update

Time sure does fly when you are having fun. As a result, I've gotten hopelessly far behind on a bunch of potentially great projects here. So my caller ID project may take a while longer. Meanwhile, I'd thought we'd bring you up to date on what's now coming down on caller ID.

Caller ID should be available in most parts of the country very soon. The controversy is dying down, since the benefits so totally and ludicrously outweigh any potential problems. To see what dozens of others are now thinking about caller ID, you might want to check #2239 CALLERID.CAP on the *GEnie* RADIO RoundTable.

If for no other use, the convenience of having a no-charge, no-hassle list of everyone that called you while you were out is just flat out wonderful. There's even an asterisk beside any

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LUMELOID AND LEPCON SOLAR RESOURCES

Key Patents:

#4,445,050 - Device for Conversion of Light Power into Electric Power.
#4,574,161 - An ordered Dipolar Light-Electric Power Converter.

Key Paper:

Lumeloid Solar Plastic Film and Lepcon Submicron Dipolar Antennae on Glass. 1990 International New Energy Technology Symposium. pages 201-210. From Planetary Association for Clean Energy below.

Key Info Packet:

From Advanced Research Development below.

Key Players:

Advanced Research Devel.
359R Main Street
Athol, MA 01331
(508) 249-4696

Dialog
3460 Hillview Avenue
Palo Alto, CA 94304
(415) 858-2700

Electric Power Research Inst.
PO Box 10412
Palo Alto, CA 94303
(415) 855-2000

Home Power
PO Box 130
Hornbrook, CA 96044
(916) 475-3179

Planetary Assoc Clean Energy
191 Promenade du portage, #600
Hull PQ, CANADA J8X 2K6
(819) 777-9696

UMI
300 North Zeeb Road
Ann Arbor, MI 48106
(800) 521-3044

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caller antsy enough to call twice.

Motorola has just announced a brand new MC145447 caller ID chip. Free sample kits are available. This one is supposed to include internal ring detection. But, as near as I can tell so far, the chip of choice remains the *Sierra* SC11211.

A FCC Part 68 interface is shown to you in figure four. Which is what normally has to go between you and the phone company. Key points include an exceptionally well balanced transformer with a 1500 volt isolation capability. While such an interface is fairly cheap and simple, getting the needed approval is not.

Several companies now offer some ready-to-go Part 68 interfaces. These are priced well above what you could build your own for. But they come pre-approved, eliminating most legal hassles. *Dallas Semiconductor* and *Cermetek* are two typical sources. An interface between the new Cermetek CH1845 and the Sierra SC11211 caller ID chip is shown in figure five.

Both *Cermetek* and *Sierra* have lots of free caller ID ap notes available.

As we've seen before, a number of ready-to-use caller ID products are available from *Hello Direct*.

New Tech Lit

From *Sony*, a new *Laser Diode Guidebook*. And from *Hughes*, a free brochure on their *Nonvolatile Serial Programmable Devices*. These gems include digital sinewave or code generators, electrically variable resistors or capacitors, switches, and counters.

The Best of Analog Dialogue is a three decade compilation of the very best in analog linear integrated circuit design info. From *Analog Devices*.

In a startling development, *real thermography* is now available for toner-based desktop publishing. One new source is *Bennet LaserBrite*. You spray on chemical A to soften your toner, dust on powder B, and then apply heat from desklamp C. Presto. Instant raised letters. Even Braille.

Free stuff this month: A video on a high end printed circuit prototyping system from *Direct Imaging*. A free video on the *Toaster*, the low cost broadcast quality video production system from *NewTek*. And a great new sample A-42 plastic electronic case from *Serpac*.

A reminder that I do have a full collection of reprints available. Just give call me for more details. ❖

Don Lancaster's
Hardware Hacker

Using the IC master
Wavelets info update
Another Caller ID chip
Piano & organ resources
Musical note frequencies

February, 1992

Several commercial products are starting to appear using that great *Rohm* BA-1404 FM stereo transmitter circuit. In particular, do check out the *Pioneer* CD-FM-1 and that *Sony* XA7A CD to auto radio adaptors. Dealer cost is in the $42 range.

What these do is let you play the output of a CD player through your existing car radio and audio system. The stereo channels are accepted by the BA-1404 IC and converted to a miniature but quite high quality FM "broadcast" signal. You unplug your antenna, plug in your adaptor, and then plug the antenna back into the adaptor. Presto. Your CD audio now appears on the FM dial as your choice of one of two pushbutton-selected low end channels.

As we have found out in the past, sloppily breadboarded BA-1404 chips tend to drift and mistune enough that they are unacceptable to most of the newer synthesized FM receivers that *demand* perfectly on-channel signals. While the ultimate way to stabilize a FM transmitter is using a frequency lock loop against a crystal reference, Pioneer and Sony both seem to have gone a simpler route.

I will present more on these two beasties after I get a chance to test them. Either one of them should hack beautifully into a FM stereo wireless broadcaster circuit.

Wavelets Update

We've had bunches of requests for lots more wavelet info. So, here is a summary of where we seem to be…

Wavelets are a stunning new set of math tools that are strongly impacting just about every region of advanced scientific study. While the keenest interest in wavelets now lies in video compression, wavelets are getting applied to everything from cardiology to seismology to animal vision, and literally everything in between.

Wavelets are a newer method of analyzing any complex set of signals and extracting useful information from those signals. Unlike the ancient *Fourier Transform*, wavelets have both *global* and *local* properties that let you selectively zoom in on signal portions of interest. For instance, good old Fourier is quite superb at working with the top and the bottom of a square wave. But the sides give it fits. Instead of Fourier's "one-size-fits-all", wavelets let you apply lots of detail only where needed.

Wavelets tend to work in a "log" manner rather than in that "linear" fashion of Fourier. Which lets you pick up any fine details when wanted. Wavelets are also great at doing the "big lumps first". This gets handy in decompressing pictures, where your crude (but complete) picture initially appears and detail later gets added. It also gives you the ability to select the amount of needed detail on the fly.

One detailed book on wavelets is *Wavelets and their Applications*, as published by *Jones and Bartlett*. The topics thoroughly covered do include wavelet fundamentals, video com-pression, digital signal processing, numeric analysis, and a bunch of advanced subjects. Sadly, the volume is written by math freaks for math freaks. It tends to run roughshod over any mere mortals. But it is there and certainly is the precise center of the emerging wavelet universe.

One tad less formidable wavelet summary tutorial and bibliography appears in that *IEEE-SP* (Signal Processing) magazine for October 1991 on pages 14-38. Note that there are dozens of different monthly IEEE publications. Make sure you get the right one.

For a useful collection of freebie reprints on wavelets for video compression, hardware chips, and design software, contact the folks at *Aware*. Wavelets do video compression far simpler, far faster, and with far fewer artifacts than the older (and now largely obsolete) DCT compression transforms. Their hardware is also far cleaner and more standard.
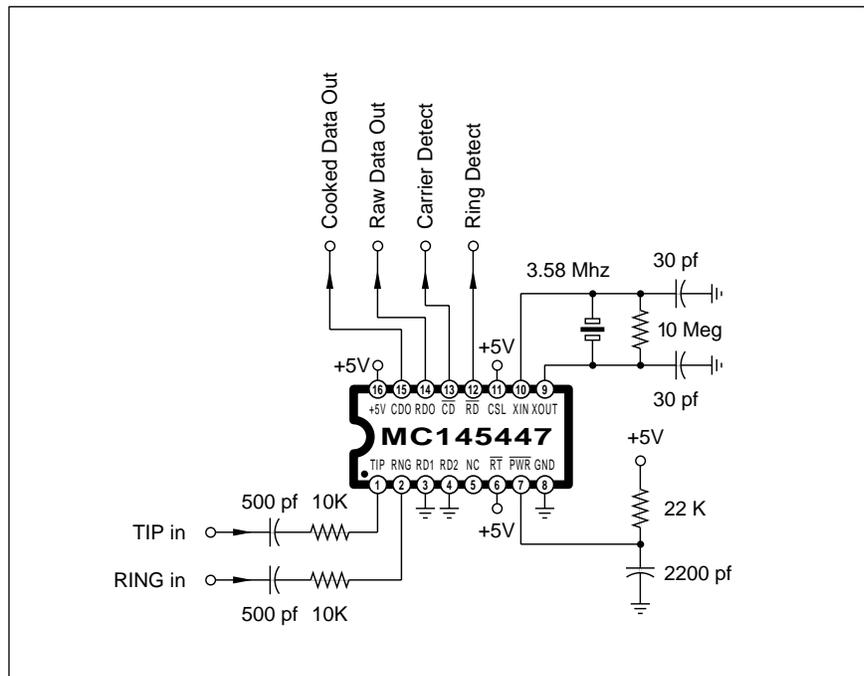

Fig. 1 – THIS CALLER ID CIRCUIT uses the brand new Motorola MC145447. Features do include internal ring detection and data header stripping. Free samples are available. The service has to be available from your local phone company before this chip can be used.

	octave 0	octave 1	octave 2	octave 3	octave 4	octave 5	octave 6	octave 7	octave 8
B	30.868	61.735	123.47	246.94	493.88	987.77	1975.5	3951.1	7902.1
A#	29.135	58.270	116.54	233.08	466.16	932.33	1864.7	3729.3	7458.6
A	27.500	55.000	110.00	220.00	440.00	880.00	1760.0	3520.0	7040.0
G#	25.957	51.913	103.83	207.65	415.30	830.61	1661.2	3322.4	6644.9
G	24.500	48.999	97.999	196.00	392.00	783.99	1568.0	3136.0	6271.9
F#	23.125	46.249	92.499	185.00	369.99	739.99	1480.0	2960.0	5919.9
F	21.827	43.654	87.307	174.61	349.23	698.46	1396.9	2793.8	5587.7
E	20.602	41.203	82.407	164.81	329.63	659.26	1318.5	2637.0	5274.0
D#	19.445	38.891	77.782	155.56	311.13	622.25	1244.5	2489.0	4978.0
D	18.354	36.708	73.416	146.83	293.66	587.33	1174.7	2349.3	4698.6
C#	17.324	34.648	69.296	138.59	277.18	554.37	1108.7	2217.5	4434.9
C	16.352	32.703	65.406	130.81	261.63	523.25	1046.5	2093.0	4186.0

Fig. 2 – THE STANDARD FREQUENCIES of the Western 12-note equally tempered music scale. Applies to most electronic and conventional musical instruments EXCEPT the piano. The piano keyboards must be "stretched" because of a piano's non-harmonic overtones.

Finally, I have posted some great IBM wavelet shareware on my *GEnie* PSRT as the file #365 WAVELET.PAK. You can call (800) 638-9636 for your connect info.

A New Caller ID Circuit

Motorola has just introduced an exciting new phone caller identification chip called the MC145447. Free samples are available. They also have a very convenient but somewhat

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The 12 equally tempered musical keys repeat each **OCTAVE**, or **2:1** frequency interval.

This means each note is related to its neighbor by a geometric ratio of the **12th** root of two, or **1.05946:1**

Only this "magic" sequence of 8-bit divisors is good enough to let all of the notes sound good together…

232 219 207 195 184 174 164 155 146 138 130 123 116

Here is the better 9-bit "magic" sequence used by the MK50240…

478 451 426 402 379 358 338 319 301 284 268 253 239

Fig. 3 – THE EQUALLY TEMPERED notes are all irrational, so only this single "magic" 8-bit sequence of division ratios can be a good enough approximation.

overpriced $100 evaluation kit breadboard that gives you a full telephone to computer serial interface.

Figure one shows one of many possible circuits. This one is intended for continuous powering.

Compared to the earlier chips, the MC145447 includes an internal ring detection and apparently can be used without an expensive coupling transformer. It optionally strips that id header off and provides only "real" message bits. That's the difference between their *raw* data output (the entire caller id byte sequence) and the *cooked* data (only the useful bytes) message strings.

Note that those two 500 pf input capacitors must be closely matched and rated to at least 1500 volts. A varistor and the normal part 68 interface should precede this circuit. The output levels are TTL or CMOS compatible, but have to get suitably translated to go over a RS-232 serial cable or data line.

The crystal used is a standard color burst frequency available for under a dollar through several of our **Radio-Electronics** advertisers.

Naturally, your caller ID service must be already provided by your phone company before either the chip or the evaluation kit will work. If the service is not yet available, suitable

machine language emulation software can be easily written for nearly any computer. The game paddle port on an Apple IIe is absolutely ideal as a fake source of id coding signals.

We'll be seeing much more on this chip and suitable emulation software after I get a better chance to more thoroughly test it. The obvious thing to do is to "steal" enough power off a computer's RS232 interface lines to eliminate any need for a stand-alone power supply. Internal power-down features of this MC145447 can greatly simplify this task.

Stay tuned for more details.

The IC Master

Finding out just who makes an integrated circuit from just the part number can be tricky. Especially if you are mistakenly reading the date code instead. As you have probably found out on your own, *Radio Shack* has a quite useful *Semiconductor Reference Guide* available for $4.

We've already seen how the two leading sources of service, repair, and replacement semiconductors are *NTE* and *ECG*. Parts and training specific to *RCA* and *GE* products are also available through *Thomson Consumer Electronics Publications*. This is an extension of the old "SK" series of replacement parts.

But *the* place to go for information on integrated circuits part numbers and cross references is a three volume set known as the *IC Master* which is published by those *Hearst Business Communications* folks. The set is not cheap – it costs $160.

Hearst also does publish the fine *Electronic Products* trade journal, plus their *EEM Master* directories. These are usually free to qualified subscribers. But note that the *EEM Master* and their *IC Master* are two totally different and separate sets of references.

Top Octave Generators

This topic is more in the realm of "whatever did happen to…" than anything else. But we still get lots of helpline calls concerning *top octave generators*, especially in the *Mostek* MK50240 family. The bottom line: These are long out of date. They also have recently become impossibly difficult to get.

The traditional western musical scale is based upon twelve *equally tempered* notes per *octave*. An octave is a 2:1 frequency interval. Each individual note gets related by the twelfth root of two, or 1.059, times the frequency of its neighbor.

The notes, of course, are lettered as C, C#, D, D#, E, F, F#, G, G#, A, A#, B, and back around to the next C one octave higher. The traditional organ people number the octaves from zero up through eight. The usual "standard pitch" frequency reference sets note A4 to precisely 440.0 Hertz.

The usual twelve-note-per-octave equally tempered frequencies appear in figure two.

Because all of these music note frequencies are irrational, they have to be approximated. One way to do this is to take a high frequency clock and divide it down by magic numbers which can hit the needed accuracy. Musicians define the interval between notes as one *semitone*, and further define *one percent* of a semitone as a *cent*. A one cent frequency error is approximately 0.06 percent.

Reasonably trained individuals usually can spot a three cent frequency error, while the best of professional musicians can resolve a single cent. Thus, the relative frequency accuracy of all the notes should be better than 0.06 percent.

To get all of the notes to sound good together, well chosen "magic" division ratios must be used. Figure three shows some detail. Of all the possible 8-Bit divisor values, only the unique sequence of 116 123 ... 232 is good enough for a three cent worst case accuracy. If you have more bits available, then other sequences are also usable.

Figure four shows you how a top octave generator works. This is an old N-channel integrated circuit that runs on a single 12 volt supply. An input clocking of 2.000240 Megahertz is required. This clock can come from a crystal for an absolute reference, or else can be variable for pitch blending or for keyboard stretching variations. Thirteen outputs are provided, giving you all the notes of the highest octave plus a spare C an octave lower.

To generate lower notes, you can either divide down the input clock for a single octave, or else add output

dividers to generate the entire music keyboard as shown in figure five.

Hackers have long ago found lots of other exciting uses for top octave generators. These include musician's pitch references, piano tuning aides, meditation and musical toys.

Perhaps one of the most off-the-wall new-age uses did involve John Simonton's *chord egg*. Polyphonic chords gotten from a lowered pitch top octave generator were chosen at random and routed to a stereo headset. By suitable delay and phasing techniques, the apparent source of the stereo sounds is forced *between* your ears, and the chords literally bounce around *inside* your head. A few chord eggs remain available through PAIA electronics.

Assembly details on a traditional top-octave generator music module system appeared long ago in the June 1976 issue of *Popular Electronics*.

There are several reasons why the top octave generators are no longer popular. The "locked in" nature of octave-shifted notes sound as a single richer tone, rather than as a separate pair of chorused voices. Having all the notes sounding all the time in the background can lead you to serious system noise problems. Zillions of wires are needed since the keyboard is usually non-scanned. The envelope and voicing opportunities are also severely limited.

But the main reason is that MIDI-based and all-digital sampled synthesizers do so much of a better job in a

far cheaper, a far simpler, and far cleaner system architecture. Besides being infinitely more flexible and sounding much better.

At any rate, new sources of top octave generators seem to be long gone. A very few of the original chips *may* remain available through *PAIA* or *Devtronix* on a catch-as-catch-can basis. It should also be possible to fake the top octave generators with programmable gate array devices. The FPGA costs are dropping rapidly enough to make this possible.

Do note that any pitch reference must be a nearly pure sinewave. Any higher harmonics will fool the ear and cause potential tuning problems.

Finally, if you know of any secret stashes of this one time great chip, be sure to let us know.

Piano and Organ Resources

I thought I'd gather together some traditional music names and numbers for this month's resource sidebar. The leading source for most piano tuning materials and supplies is at *Tuner's Supply*, while the best source for antique instrument parts and data is the *Player Piano Company*. And a good horse's mouth book is *Piano Tuning and Allied Arts*.

But do note that piano tuning is (1) A lot harder than it appears; (2) A miniscule, unprofitable, and rapidly declining market; and (3) an easy way to cause irreparable damage.

Note also that most piano keys are *never* tuned to all their "correct" fre-
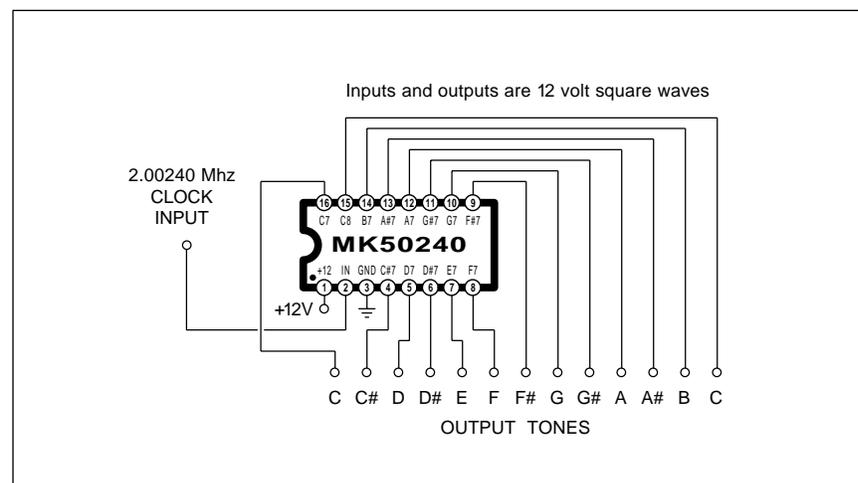
Fig. 4 – TOP OCTAVE GENERATOR integrated circuits produce all the needed notes of the musical scale. Input or output lines can be binarily divided for lower octaves. Sadly, these chips are getting hard to find.

quencies. Instead, the keyboard has to be "stretched" to allow for the non-harmonic nature of real world string overtones. And that it takes several *weeks* to properly tune a piano.

One classic kit organ company is *Devtronix*, while *PAIA* offers a wide range of traditional to new age kits.

An excellent source for electronic music titles is the *MIX* Bookshelf, stocked by the folks that also publish the *Electronic Musician* magazine. Fundamental synthesizer secrets can often show up first in the *Journal of the Audio Engineering Society.*

Some additional electronic music resources do appear in my *Hardware Hacker II* reprints.

New Tech Lit

A great "gottahave" *Video Data Handbook* from *Signetics Philips* that is chock full of digital video interface chips, RGB digitizers, multi-media chips, sync strippers, color decoding, and the usual A/D and D/A conversion chips and circuits.

Speaking of multimedia, the *Media Magic* people do offer a *Computers in Science and Art* catalog full of good books, tapes, and software.

A free bibliography of papers on

microwave plasma applications is offered by *Astex*.

From *Antique Electronic Supply*, a 1992 wholesale catalog of supplies, books, tubes, info, and parts for the electronic collector. We've had lots of calls from experimenters trying to find Fahnstock clips in this day and age. These folks are one of the few remaining suppliers.

Another trade journal on magnetic and electric shielding ideas is *EMC Technology*. And a wide selection of aircraft hacker books is available by way of *Aircraft Designs*.

This month's freebie mechanical samples include foams, films, and foils from *ARclad*, a *Foam Specifier Kit* from *Voltek*, and some self-stick bumpers from *ITW/Fastex*.

A reminder that I have recently revised my *Incredible Secret Money Machine II* and now do have auto-graphed copies on hand for you when you call or write. You can get the ISMM by itself or as a portion of my *Lancaster Classics Library*.

You can also reach me via *GEnie* PSRT (800) 638-9636 where you will find hundreds of downloadable files and tutorials on hardware hacking and midnight engineering topics.
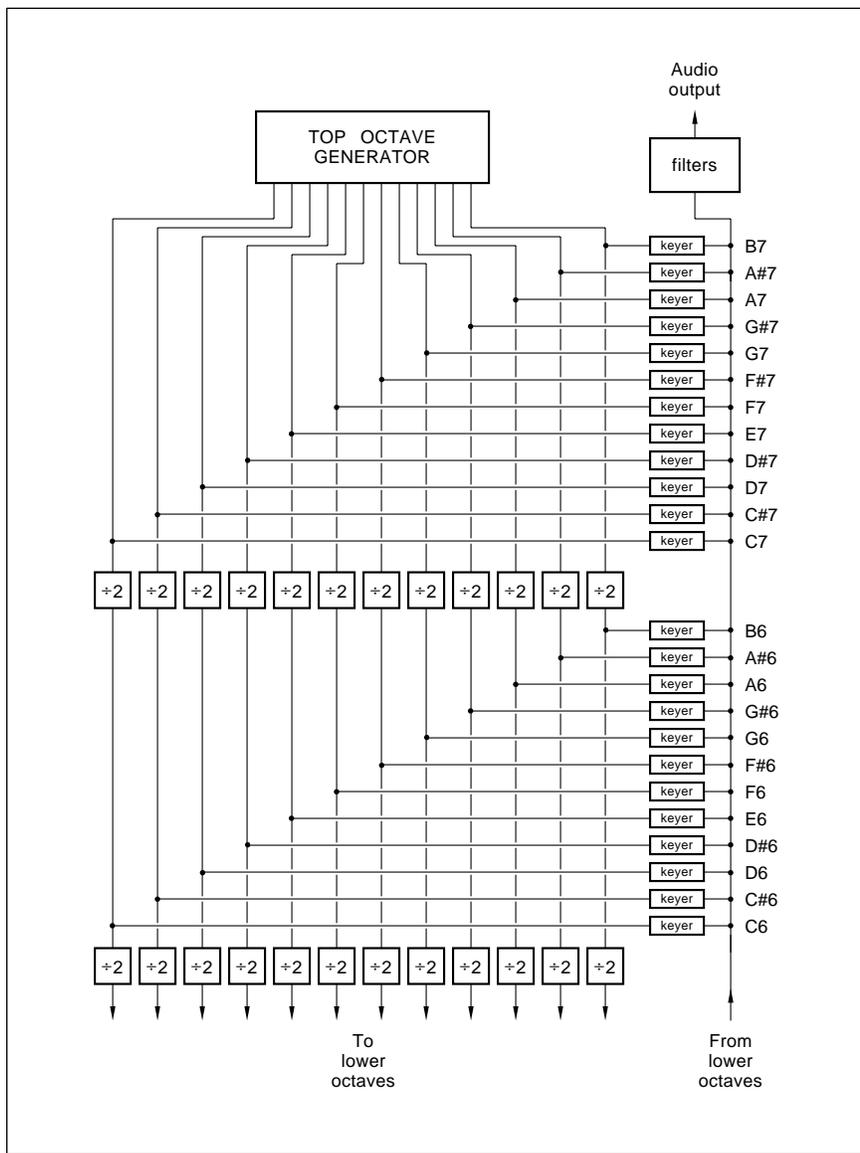
Let's hear from you❖

Fig. 5 – A TRADITIONAL ELECTRONIC ORGAN architecture using top octave generators and dividers. Today's MIDI-based sampled synthesizer circuits produce far better sound simpler and in infinitely wider variety.

Don Lancaster's
Hardware Hacker

March, 1992

We will start out with our usual reminder that this is your column and you can get lots of technical help, off-the-wall networking, plus consultant referrals per the box below. Your best calling times are from 8-5 weekdays, mountain standard time.

But please, before you call, make sure that the answer isn't already in the text or in the *Names and Numbers* or in our occasional special resource sidebars. And please have a pencil or pen handy. I just cannot believe the number of calls I get that either refuse to look at or can't find the sidebars.

I am also greatly expanding our informal PostScript *Hardware Hacking Consultants Network*. Send me a letter or give me a call if you wish to participate.

We also do have special *Hardware Hacker* and *Midnight Engineering* topics up on *GEnie* PSRT. You could reach me via [SYNERGETICS] email here to get the preprints, reprints, tutorials, and other great downloads in our ongoing experiment in electronic on-demand publishing. Plus, receive late breaking news (especially on PostScript, solar energy, and caller ID) literally as it happens.

We do have lots this month on the *Super Nintendo* interface. But first…

A GPS Update

We sure had strong reader interest in our GPS navigation story from two columns back, so here is a quickie update:

That GPS, (for *Global Positioning Satellite* system) is a flock of roving satellites which do broadcast spread spectrum codes on 1227.6 and 1575.2 Megahertz. By receiving these signals and digitally processing them, you can obtain your exact position and speed anywhere in the world. To an absolute accuracy of a hundred feet or so, and a potential relative accuracy of an inch or less. Thus GPS can be used for long distance navigation *and* for accurate surveying.

The horse's mouth key paper you need is known as the ICD-GPS-200

document and is obtainable at no charge to US citizens through *Space Systems Division/MZEE*. You must send them a letter stating your name and purpose.

A great $12 Dan Doberstein reprint titled *A GPS Data Receiver* is newly available through *DKD Instruments*. This includes an excellent tutorial on GPS, full construction details on his ham radio style GPS receiver, and an extensive bibliography. The receiver is both data-only and an older analog design. While specifically designed with hardware hacking in mind, this receiver is definitely not a "shake the box" project. You'll need microwave, digital logic, rf design, and software skills to sucessfully complete it. Your costs are also likely to be very much higher than by using a modern digital chip set as well.

Good nav technical papers often do appear in the *Journal of the Institute of Navigation*. These folks also have a new three volume *GPS Resource File* available for $50.

The prices of the commercial GPS

receivers are literally in free fall, and I'd expect a $35 chip set and a $79.95 receiver within five years. Today's best offer in a high quality receiver useful for trucking companies and such appears to be the GPS-1 from *Loyola Enterprises*. The current list price is $795 plus software.

Note that all the GPS signals are right on top of each other and deeply buried in background noise, so any old surplus microwave receiver tuned to the GPS frequencies will show you nothing useful at all. Special digital *despreading* circuits *must* get built into your receiver.

I'll try to work up a tutorial on GPS in a future column. But I think I'd better first do some background stuff on the very fundamentals of digital correlation and spread spectrum communications. Whenever.

Video Sync Separation

Another popular helpline topic is video interface. And the number one ongoing request is for a simple and effective sync separator. The *sync*
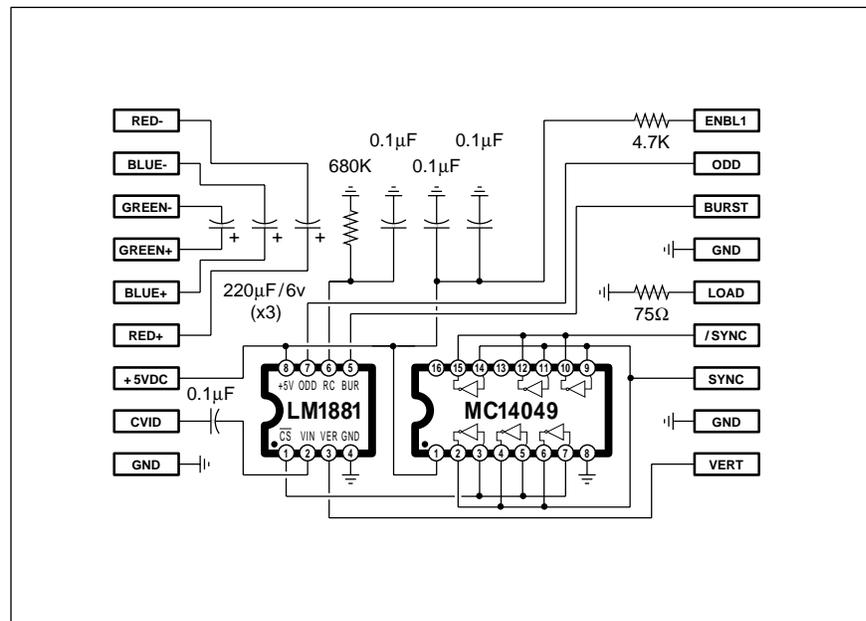

Fig. 1 – THIS COMBINATION SYNC STRIPPER and universal video interface can solve a lot of problems for you, including Super-Nitendo-to-anything interfacing, video overlay, and scope TV frame locking. Kits, fully tested units, and custom cable assemblies are available through Redmond Cable.
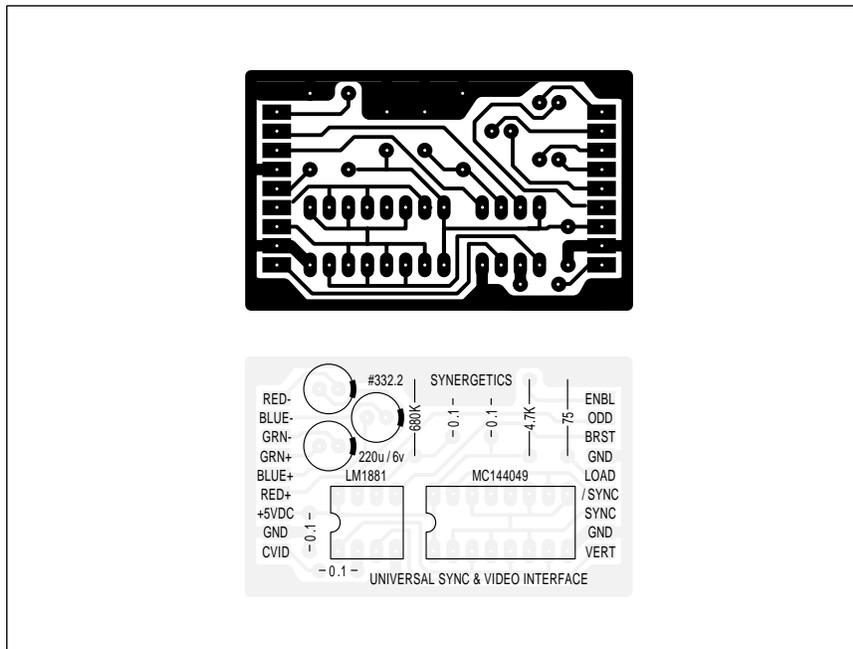
Fig. 2 – PRINTED CIRCUIT BOARD LAYOUT and overlay for the universal video interface. Accurate and camera-ready art is also available via GEnie PSRT as file HACKFG51.PS. PostScript downloads can easily eliminate all of your darkroom work.

separation process lets you take your normal composite video signals and extract those horizontal and vertical synchronizing pulses from it.

The most obvious use for a sync separation is to let you clearly view video signals on your oscilloscope. Without a field or frame reference, all you will see is a blur. Other uses for sync separation do involve stripping closed captioning or other data off specific horizontal lines present during vertical retrace, grabbing stock quotes, inserting windows, pattern generators, title overlays, wiping and fades, color keying, and other special effects. Or simply adding a pair of crosshairs.

Figure one shows you a simple and low cost circuit I've worked up that can combine both an effective sync separator and a low cost universal video interface card. The key chip is the *National* LM1881 sync separator mini-dip. You take your usual one to two volt positive going *sync=ground* video signal and capacitor couple it to pin 2. The chip extracts the composite video and produces the active low TTL/CMOS compatible composite sync output on pin 1.

Several other pins on the LM1881

provide other functions that you may find handy. Pin 3 gives you a vertical sync reference as one single pulse without the usual teeth or serrations. This is the one you will usually want to lock your scope to. Pin 5 is a burst gate that gives you a slightly delayed horizontal sync pulse that can be used to extract any NTSC (Never The Same Color) chroma burst info.

An RC network found on pin 6 is intended to create a default vertical sync in absence of a true NTSC video input. This is handy for the "almost" NTSC common to the computers and video games. The time constant can be shortened for higher scan rates; see the National data sheet for details.

Finally, pin 7 lets you pick out the odd and even fields of an interlaced NTSC frame. This output is active only when the input composite video has a full interlace. Advanced color editing is one possible use.

An external source of the usual five volts DC is needed. Since the current is only seven milliamperes, just about any old supply will do. As usual, keep the power bypass caps real close to your chips.

Several other features on the circuit are handy for special video interface

cables. The three large capacitors let you couple red, blue, or green video off emitter follower outputs and then connect them to RGB monitors. A 75 ohm resistor is handy for terminating cables. And a logical high signal is useful for such things as enabling the sound on certain receiver/monitors.

By itself, the inverter is handy for converting active low sync into active high and vice versa. While most of the video systems do use active low sync, *Commodore* and one or two of the others may not.

The printed circuit layout is shown you in figure two. Empty boards, kits, tested circuits, and both stock and custom interface cables are available from *Redmond Cable*. You can call or write them for a current price list. I'll also post this layout on *GEnie* PSRT, so you can easily create your own accurate version without needing any photo work. See HACKFG51.PS.

You may want to keep some empty or partially populated boards on hand to solve special cabling and interface uses. The large runaround ground on the outside is especially handy for shielded cable terminations.

For this month's contest, just tell me about an unusual or off-the-wall use for a sync stripper circuit. There will be all of those usual *Incredible Secret Money Machine II* book prizes, along with an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all. As usual, send your written entries directly to me at *Synergetics*, rather than over to **Radio-Electronics** editorial.

Let's hear from you.

Nintendo-to-Anything Interface

As figure three shows us, there's a *very* interesting *Multi-Out* connector on the back of those *Super Nintendo* game machines. This gives you lots of alternate video and sound output formats that you might find handy.

For instance, you can go to a RGB monitor for sharper images and better colors. Or add total stereo sound or Super VHS improved resolution.

Or, you may want to hang any old tv-compatible color monitor plus a pair of headphones on the machine to silence kids and keep them off your main prime time television set.

Let us see exactly what is on this connector and how to use it. By a

special arrangement with *Redmond Cable*, all the connectors, the above interface kit, and special and stock cable solutions for almost *any* Super Nintendo interface are available.

The Multi-out connector is really six-over-six edge traces on a double sided circuit board. Looking at the rear, the traces are odd numbered 1,3,5,7,9,11 on the top, going right to left. And the similar pins are even numbered 2,4,6,8,10,12 on the bottom, again going from right to left.

Both pins 7 and 8 are grounds. The pair make terminating several shielded wires much easier.

A +5 vdc output is provided on pin 10. It appears to be capable of driving at least 50 milliamperes. But you shouldn't suck the poor machine dry, and you should very carefully bypass and filter any use of this supply.

There are a pair of sound outputs. Pin 11 is your choice of monophonic sound or a (L + R) matrixed stereo. Note that "left" plus "right" equals "both". Pin 12 is (L - R) matrixed stereo. These signals are capacitor coupled and are the proper size for your usual audio inputs on a hi-fi receiver or computer monitor.

Note that some computer monitors have a sound capability and some do not. The easiest way to tell is to find an obvious *volume* control located somewhere on your set. No volume control, no sound. Other monitors may need a special pin activated to turn the sound off or on. We'll see an example of this shortly.

All your sound cables should, of course, be shielded.

Sadly, the power levels are far too low to usefully drive a speaker or a pair of headphones. But *Radio Shack* has an interesting beastie which no Hardware Hacker should be without. It is their #227-1008C mini-amplifier and speaker. The (L + R) output easily drives this mini-amp, by way of a standard miniature phone plug.

This mini-amp solves the problem of a monitor that has no sound. You can also plug headphones into your mini-amp for any silent running. The mini-amp is powered by your choice of an internal alkaline 9 volt battery or by a plug-in 9 volt dc supply.

Because of the matrix used, you cannot get stereo directly off of pins 11 and 12. Instead, you have to *add*

7 | SUPER VHS "Y"
The luminance channel for Super VHS video appears on this line.

One volt peak to peak into a 75Ω load. Internally capacitor coupled.

9 | NTSC VIDEO
Plain old NTSC composite video appears on this line. The sync tips are at ground.

One volt peak to peak into a 75Ω load. Internally capacitor coupled.

11 | L+R SOUND
The monophonic and stereo matrixed sum sound appears on this pin.

One volt peak is suitable for amplifiers but not headphones.

12 | L-R SOUND
The stereo matrixed difference signal appears on this pin.

Add pins 11 and 12 for left stereo; subtract them for right stereo output signals.

10 | +5 VOLTS DC
A limited amount of +5 volts supply power may be drawn out of this pin for sync inverters or doing a stereo dematrixing.

Limit current to 50 milliamperes and use thorough bypassing.

8 | SUPER VHS "C"
The chroma channel for Super VHS video appears on this line.

One volt peak to peak into a 75Ω load. Internally capacitor coupled.

5 | GROUND
A pair of ground pins is provided to ease terminating of shielded video and audio cables.

3 | /RGB SYNC
For linear RGB monitor use. Active low combined vertical and horizontal sync pulses.

0 to 5 volt high logic source is CMOS and TTL compatable.

1 | RED VIDEO
For linear RGB monitor use. One volt peak-to-peak off of an emitter follower source.

Requires a series 200 µfd coupling capacitor.

2 | GREEN VIDEO
For linear RGB monitor use. One volt peak-to-peak off of an emitter follower source.

Requires a series 200 µfd coupling capacitor.

4 | BLUE VIDEO
For linear RGB monitor use. One volt peak-to-peak off of an emitter follower source.

Requires a series 200 µfd coupling capacitor.

6 | GROUND
A pair of ground pins is provided to ease terminating of shielded video and audio cables.
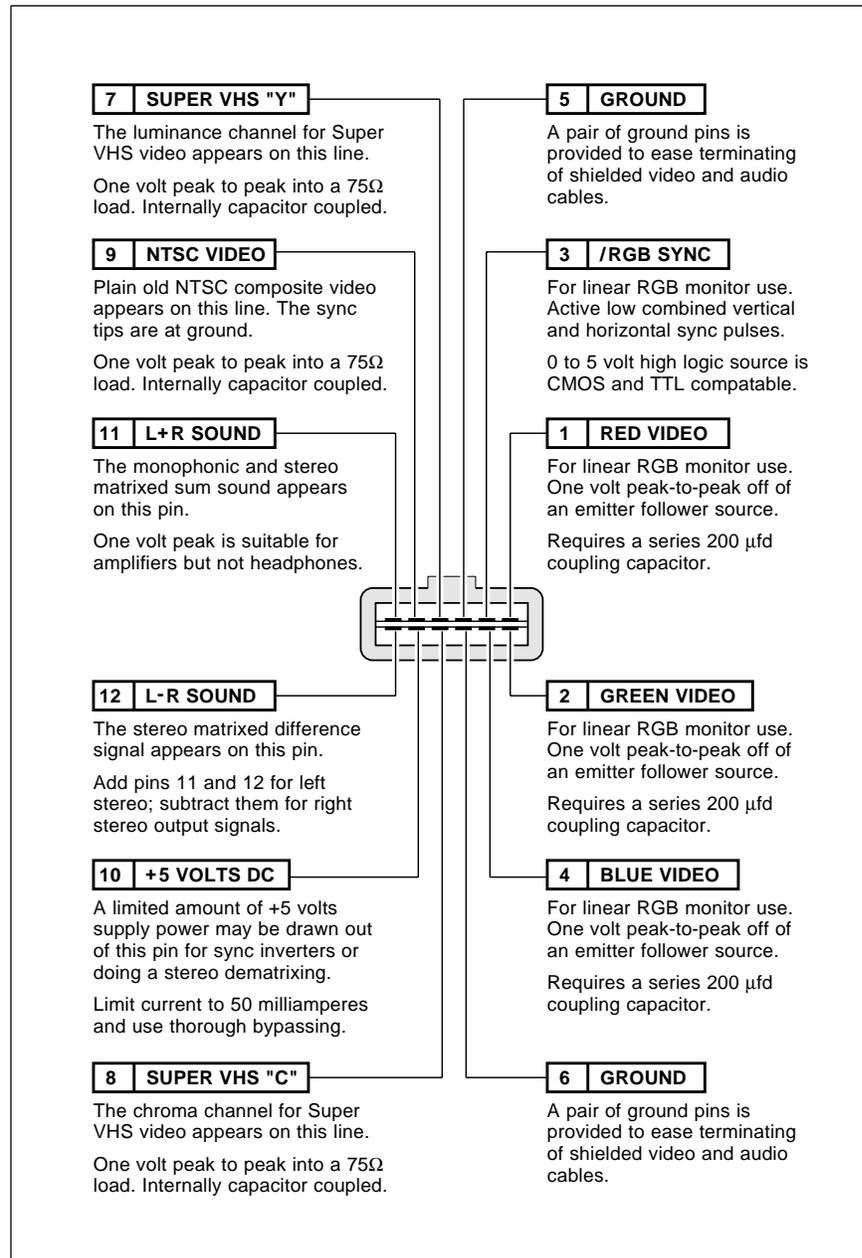
Fig. 3 – THE SUPER NINTENDO MULTI-OUT REAR CONNECTOR has all sorts of useful video and audio options available. Here are the key details.

the two signals together to get the left channel, and *subtract* the two signals from each other to pick up the right channel. Like so…

$$(L + R) + (L - R) = 2L$$
$$(L + R) - (L - R) = 2R$$

A stereo dematrix can be done with a quad op-amp or a transformer and four resistors. In theory, you could make use of a CMOS biased inverter amplifier, but your common mode

supply noise rejection might suffer on your right channel. More details on biased inverter amplifiers appear in my *CMOS Cookbook*.

Let me know if you need any more info on stereo matrix extraction.

There are three different types of video outputs found on the multi-out connector. Plain old grounded sync composite video appears on pin 9. This can be routed to any standard NTSC video input on a monitor, VCR

or television set. Note that a direct video input will often have sharper images and better colors than does entry by way of some channel 3 or 4 modulator. Simply because far less electronics gets in the way and an RF modulation and demodulation can be eliminated.

Super VHS or Y-C video appears on pins 7 and 8 with that luminance "Y" output on pin 7 and the chrominance or "C" output on pin 8. These can be routed to any system which accepts Y-C video. Because of the separation of all the color information and the higher bandwidths, these Y-C outputs should look far better than regular composite video.

The best video of all, though, is available as a separate red (on pin 1), green (pin 2) and blue (pin 4) video. These red, blue, and green outputs do come off from emitter followers and have a strong dc bias. They *must* be capacitor coupled to your ultimate destination using a 220 microfarad or higher series capacitor on each line. Be certain to put the (+) side of the capacitor on the Nintendo end.

The needed RGB sync appears on a fourth active low line on pin 3. The active low sync is correct for Apple IIGS, Sony, and most "standard" RGB uses. It is the complement of what is needed for *Commodore* and certain others. The line swings ground to

+2.4, but is only weakly TTL compatible. More on this next month.

Note that some connector plugs do not have all of their pins available, especially for the RGB sync and VHS chroma. The Redmond plugs include all of the pins.

Several interface circuits appear in figure four. In each case, a partially populated figure one circuit can be used to greatly simplify your cables and interface.

In figure 4-A, you can connect RGB video to any Apple IIGS monitor by using the three serial video capacitors and the right connector on each end of your cable. Since the IIGS monitor has no speaker, you have to use a hi-fi or the Radio Shack mini-amp.

Figure 4-B, shows an interface to the older *Sony* KV1311-CR receiver/ monitor. Again, we have those three serial video capacitors. This time, we use an enabling resistor to turn on the internal sound and eliminate any need for a companion amplifier.

The interface to the *Commodore* 1084 color monitor is shown in figure 4-C. As usual, the red, blue, and green video have to be capacitor coupled to the appropriate pins on the *LinRGB* connector. This time, an active-high sync is needed rather than active-low, so the inverter must get added as shown. While the sound is internal, it has to be routed via a separate audio cable and phono plug that goes into the *Audio* input. The size and position adjustments on the back may also need a slight readjustment.

Yes, we are working on VGA and multi-sync solutions. Stay tuned or check *GEnie* PSRT for availability.

Once again, some mix and match kits, all-pin connectors, parts, and cables are available from *Redmond Cable*. Do let me know which other interface circuits you would like to see worked out.

Laser Printer Repair Resources

Where can you go to get training, parts, and information on today's laser printers? Many of the printer manufacturers are super secretive and go far out of their way to prevent you from getting the parts and materials you need to best use your printer and to cheaply keep it alive. So, for this month's resource sidebar, I thought we'd gather together some of the best

(A) APPLE IIGS A2M6014 MONITOR

(B) SONY KV1311CR RECEIVER/MONITOR

(C) COMMODORE 1084 MONITOR
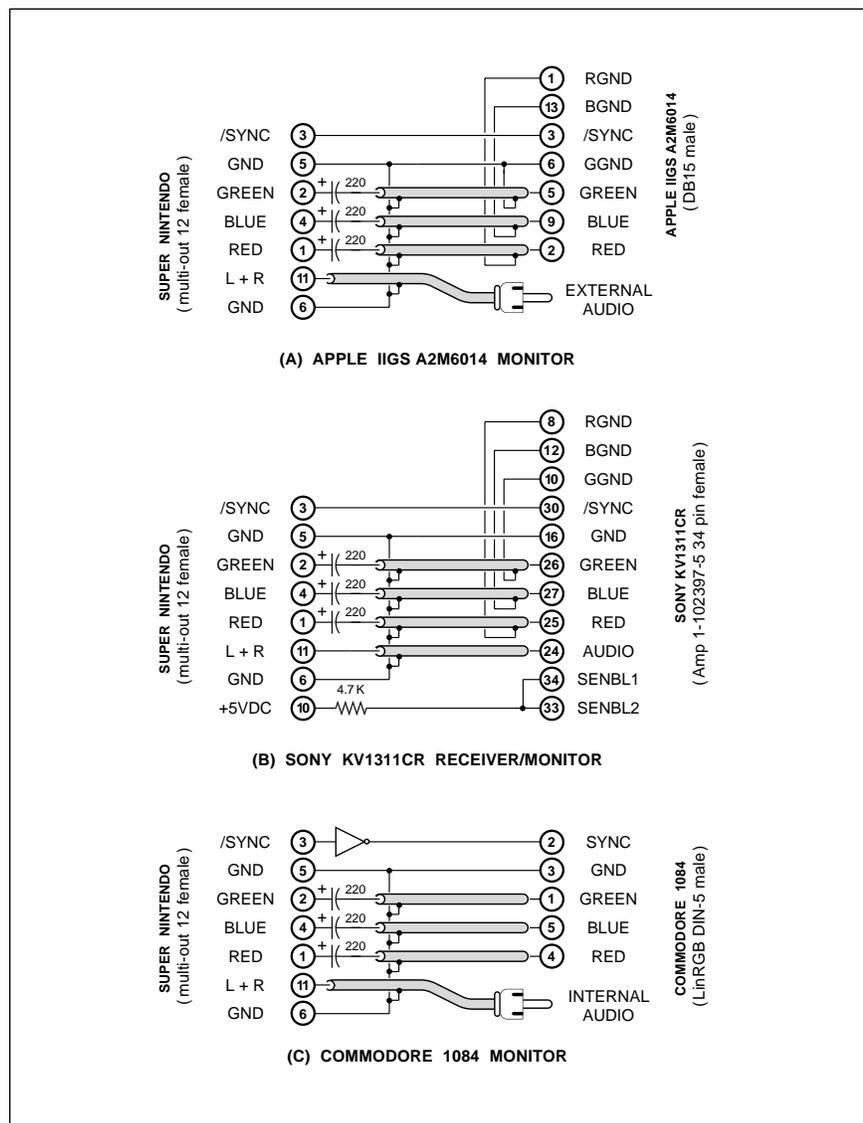
Fig. 4 TYPICAL SUPER NINTENDO TO LINEAR RGB VIDEO MONITOR interface connections can give you sharper resolution and better colors.

of the laser repair resources.

The overwhelming majority of all laser printers use *Canon* engines, so that is usually where you'll want to start. *Hewlett Packard* has by far the best and the most available Canon manuals in the industry. And since a SX engine is a SX engine, those HP manuals are most useful on similar *Apple*, *QMS*, and lesser machines.

Figure five summarizes the key HP service manuals, along with some of the competing machines they cover. HP recently has sharply raised all of their service manual prices. Many are in the $100 range. Even at this price, they pay for themselves on their first use. They are essential gottahaves.

HP does also sell parts to anybody overnight via VISA and an 800 order line. Again sadly, individual parts are hard to get. They prefer to sell you an entire $50 fan instead of the 50 cent grommet which is the only thing that ever goes wrong with the fan.

The best place to go for individual parts is *Don Thompson*, who also now offers by far the finest of multi-level training and repair seminars in the entire industry.

My two favorite places for toner refilling supplies and materials are Arlin Shepard of *Lazer Products*, and Walt Jeffries and his crew at *Black Lightning*. The latter are also into the special toners for fabric printing and printed circuits as well.

Black Lightning also publishes *The Flash*, a free and friendly newsletter crammed full of useful desktop info.

There are several laser printing and toner recharging trade journals, but the only one of any consequence is *Recharger*. They are already up to several hundred pages per issue, and list dozens of suppliers for just about any laser printing repair need.

I do try to carry a lot of toner and laser printer repair stuff on our *GEnie* PSRT. We also have on-line real time conferences with the leaders in this field. Both those upcoming and as bunches of downloadable transcripts. These files usually will start off with an "RTC" prefix.

New Tech Lit

From *SGS/Thomson* a new *Modem Databook and Applications* manual. From *Benchmarq*, a *1991 Databook* on their energy management (power switching) chips for laptops, real time clocks, and non-volatile memories.

A new and very thorough *Heatsink Application Handbook* is available from *Aham Tor*. TV satellite products and info are offered by *AIS Satellite* and *Skyvision*. Both do provide free catalogs. Skyvision has a very good satellite book selection.

Our two new trade journals for this month include *Electronic Product Review* on new component parts and *CADalyst* for those users of AutoCad

CAD/CAM systems.

Those folks at *Small Parts* always have been a great place to go for all the robotic and mechanical stuff your hardware store never heard of. As well as any precut plastic and metal shapes. They have recently moved to larger quarters, so you may want to note their new address and pick up a new and free catalog.

A free *School Shop* catalog from *Rutland* offers all the usual machine shop tools and supplies.

As per usual, most of the *Names & Numbers* are shown in the ending appendix, while the *Piano & Organ Resources* appear in their own sidebar shown above.

A no-charge sample of backlit fiber optic displays is newly available from *Serigraph*, while the *Caplugs* people offer a free sample *idea kit* on their plastic plugs, caps, and enclosures.

A reminder that I now do stock my *Active Filter Cookbook* for all of the fundamentals of quickly building up your own analog lowpass, bandpass, and highpass filter circuits. I've got autographed copies on hand for you here at *Synergetics* when you call or write. You can get this book by itself or as one portion of my *Lancaster Classics Library*.◆

HP MANUAL	HP PRINTER	APPLE PRINTER	QMS PRINTER
02686-90920 (CX Engine)	LaserJet I	LaserWriter LaserWriter Plus	PS800
33449-90906 (SX Engine)	LaserJet II LaserJet III	LaserWriter NT LaserWriter NTX LaserWriter F LaserWriter G	PS810 & Turbo PS820 & Turbo PS815-MR PS825-MR
33459-90906 (SX Engine)	LaserJet IID LaserJet IIID	– – – –	– – – –
33471-90904 (LX Engine)	LaserJet IIP	Personal LW NT	PS410
33491-90929 (SI Engine)	LaserJet IIIsi	– – – –	– – – –

Fig. 5 – THESE HEWLETT-PACKARD LASER SERVICE MANUALS can be used for mechanical repairs on most of the printers shown here. While expensive, they are the best info available, and far easier to get than many of the others.

Don Lancaster's
Hardware Hacker

May, 1992

Let's start off with an update to those Nintendo interface circuits we looked into last month. For those of you who came in late, you will find a special connector at the rear of the *Super Nintendo* machines that can let you connect up to stereo amplifiers, headphones, RGB monitors, *Super VHS* recorders, and bunches more.

We did look at this connector in some detail last month and we saw several useful and low cost interface circuits. And we found that *Redmond Cable* offers all sorts of custom and stock video game interface kits.

But after some further testing, the RGB SYNC line on a *Super Nintendo* connector pin three is not quite what it appears to be. As figure one shows you, this pin *looks* like it should be both CMOS and TTL compatible, but it is not. You can't pull it up fully for CMOS and there isn't enough current sinking capability for much of TTL. Some (but not all) RGB monitors will refuse to lock to this output.

The problem is that the output does not come from a "real" logic gate. It apparently arrives from an emitter follower which has a weak pulldown resistor. And a low supply voltage.

There seem to be several simple workarounds you can try. The easiest is to add the external 680 ohm resistor shown. This should give you enough current sinking for typical LS TTL inputs. Use a scope to verify your levels. There is even a place on last month's circuit board for the resistor.

Otherwise, you should be able to directly interface to any low cost but rare 74HCT CMOS logic. Or you can use the sync stripper circuit we saw last month as a substitute, deriving your sync from the composite NTSC video instead.

Finally, next month we might look at a simple *sync amplifier* which also will be needed for an upcoming new *Neo-Geo* interface. It should also work and is based on adding feedback to a 4049 inverter to make it into a simple ac amplifier.

So do stay tuned.

Ockham's Razor

See, I even got the spelling correct. William of Ockham was a fourteenth century English philosopher. Paraphrased, Ockham's really big thing in life was that "The simplest possible explanation is usually the best – and probably also the most correct." And *Ockham's Razor* can be your ongoing process of slicing away and reducing everything to its bare (but still quite correct) essentials.

Very few engineering design courses ever mention Ockham. But his razor should be the very center of virtually *all* engineering design, *all* analysis, development, debugging, and repair. So, I thought I'd use Ockham's razor as an excuse to gather together and simplify the few loose helpline odds and ends that I've been meaning to comment on anyway…

Cold Fusion– Ockham says they had their chance to get their act together and they blew it. Yes, strange amounts of heat can apparently be produced in highly unusual lab circumstances. No, such rather mundane reasons as hydrogen fires, mixed gas fuel cells, or an embrittlement stress relief have not been totally ruled out. And no, I have not seen so much as one credible and reproducible shred of evidence that anything atomic is in

fact coming down. Barring any new developments, cold fusion seems to be on hold. And probably remains a sucker bet for hackers at this time.

Pseudo Radio Astronomy– Several years back, a "radio astronomy" receiver appeared in RE that seemed to be responding to extragalactic signals in a circuit which was vastly simpler than those used by far more credible researchers. I've often been asked for my comments on this, so…

Ockham says the circuit was just a simple analog thermometer that was measuring the temperature drift of the offset voltage of a 741 op amp. When the sun set, so did the 741. And the circuit capacitors that mysteriously acquired charge are no mystery at all. The effect is known as *bounceback* and has to do with lateral charge migration in a dielectric.

Utility linemen do learn all about bounceback in lecture one of day one in lineman's school. And there is a very simple way to spot any utility lineman who knows all about bounceback: They are the ones still alive.

Now, this circuit may or may not have in fact been receiving the extragalatic signals. But the temperature drift and bounceback effects clearly would have been many millions to many billions of times larger. Thus there would be no way to tell until all
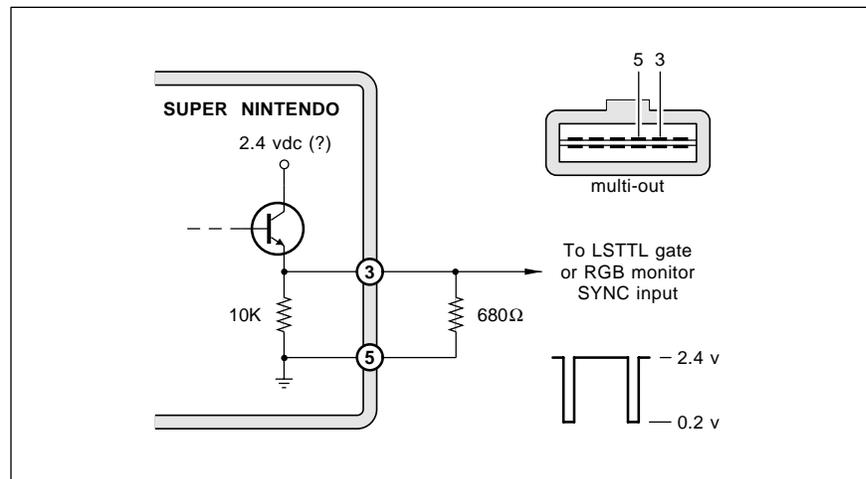
Fig. 1 – THE SUPER NINTENDO RGB SYNC output only looks like it is TTL or CMOS compatible. Add the external resistor shown for a LSTTL interface.

of these first order effects have been carefully and painstakingly removed from the circuit.

The Newman Motor– The Newman Motor is (or was) a perpetual motion machine that still seems to be ekeing out a meager existence on late night talk shows. This one-time media circus has been around for a decade or more. Yet, for some strange reason, working models still remain few and far between. Now, *if* we're going to grant the true believers that something weird was in fact going on, then Ockham's razor reduces it down to "sparks *may* lengthen battery life."

Which *might* bear further looking into as a hacker topic. An ordinary flashlight cell does not yield all of its chemical energy whenever it "runs down". Clearly, if so much as a tiny scrap of the zinc case remains, then recoverable chemical energy may still remain. At least in theory. Instead, a cell will *polarize* and thus raise its series resistance to the point where it can no longer deliver useful power.

What if you *recycle* a fraction of the power back *into* the cell as a high current pulse? Say ten amps for ten milliseconds per second in for every continuous one amp out? Could this in fact partially delay the increase of cell resistance by slowing down the polarization process? Or maybe just warm the cell up to a more optimum power delivery point?

Note that electroplaters do this all the time. They occasionally *reverse* their plating process and purposely *unplate* for a while. This improves the smoothness and does other good things to the finish.

The obvious things to ask here are "Does energy recycling help us at all?" and "What are the optimum recycling pulse strengths and best duty cycles?" "Does any higher frequency ac help?" And, of course, "Even if all of these effects do significantly improve life, are the economics there?"

Let's have your thoughts on this. Cell energy recycling does look like a reasonable and legit research topic. But a warning: do keep your target carbon-zinc cells in a suitable "bomb shelter" such as a paint can full of sand. And do be careful.

Microcontrollers – The breakeven point between using and not using a CPU and RAM-ROM-I/O architecture in any Hacker project was passed a decade ago. Ockham says that it's now ridiculously faster, cheaper, and far better to include the microprocessor these days, rather than foolishly trying to leave one out.

Yet I get all of these strange calls for projects that require such things as keyboards, displays, fancy timing, strange sensors, and miniscule markets which could be done insanely faster and cheaper by (A) first making a model with a $30 Commodore 64 from a yard sale and then, if really needed, (B) working out a one or two chip RAM-ROM-I/O solution.

Besides lots of really great microcontroller projects found right here in **Radio-Electronics**, you'll find lots of others over in Steve Ciracia's *Circuit Cellar Ink*. And I do offer my *Micro Cookbook I* and *Micro Cookbook II* that can get you started on many of the fundamentals.

Wireless Broadcasters

One of the less pleasant hacker surprises recently is that most low cost FM wireless broadcaster circuits flat out will no longer work. Older analog FM radios could get tuned anywhere across the entire band and had a very strong AFC or *automatic frequency control* circuit which would lock onto a non-standard signal and track it anywhere. But nearly all of today's totally digitally synthesized FM receivers (especially most car radios) absolutely *demand* the transmitted signal to be precisely locked onto one of the FM broadcast channels.

Designing any high quality FM transmitter that is both ultra stable and able to be rapidly and linearly frequency modulated gets tricky fast. Because you are asking for a circuit that both will and will not change its frequency. The "technically correct" high end solution is to use an indirect circuit known as the *frequency lock loop*. The average output frequency from your transmitter gets divided down using a counter and compared against a crystal reference. An error signal is then derived phase lock loop style and used with varactor diodes to continuously force your transmitter back onto the correct frequency.

Hams have long chosen a simpler technique called *crystal pulling*. Your average crystal is *slightly* sensitive to reactive loading in a circuit. The rule of thumb is that you can pull a plain old crystal around *one-tenth percent*. But crystal pulling is usually highly nonlinear. And limited in range.

To pick up enough deviation, hams would start off with a low frequency crystal and then multiply up into their final 145 Megahertz or whatever freq
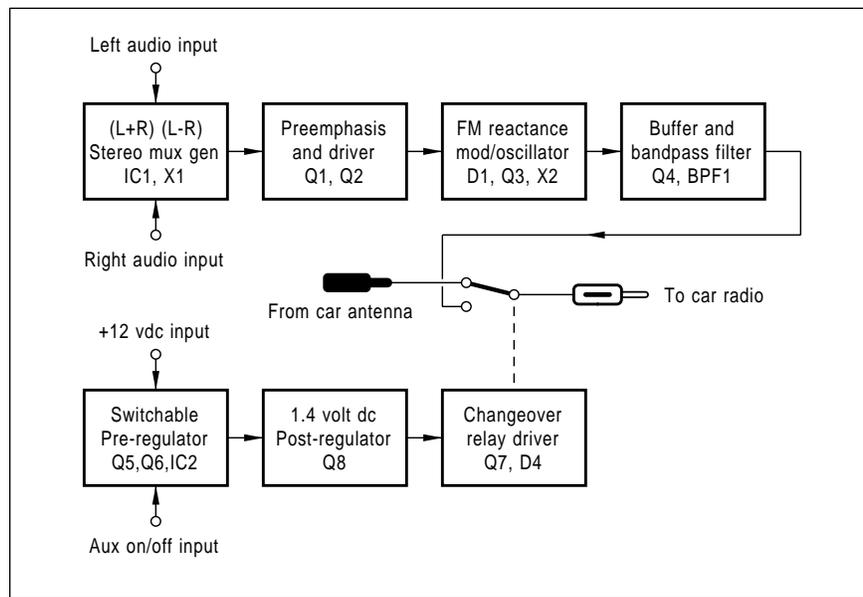
Fig. 2 – MOST LOW END FM WIRELESS BROADCASTERS simply will no longer work, because nearly all the newer synthesized receivers now DEMAND precisely on-channel stations. The Pioneer CD-FM-1 (block diagram shown here) generates exact frequency stereo FM signals.

range. Typical hams rarely concern themselves with any wide deviation broadcast quality audio. In fact, they are not allowed to do so.

Apparently both *Sony* and *Pioneer* have figured out how to linearly pull a special third overtone HF crystal to *directly* let you do a full CD quality FM stereo transmitter that is precisely locked onto your correct frequency. Sony's product is called the XA-7A, and Pioneer's is the CD-FM-1. While the intended use of these units is to let you conveniently add a CD stereo player to your car radio, either one will apparently make up most of the critical circuitry for an excellent and very high quality FM stereo wireless broadcaster. Dealer cost of these is in the $42 range, and they seem to be fast and fun to hack. And offer both on-channel locking and near-broadcast quality. We will look at the *Pioneer* CD-FM-1 here.

Obvious uses for a short range FM broadcaster include "Please buy my house" messages for drivebys; baby sitting or handicapped monitoring; and cord-free audio for a teacher, a public speaker or a video actor. But there's also zillions of non-obvious uses, including such things as getting data onto or off of a rotating shaft and short range rocket telemetry.

Limited range and limited power FM broadcasters are now generally allowed by the FCC, while the more powerful units have to meet specific licensing and certain type approval requirements. More details on getting and meeting FCC specs appear in our *Hardware Hacker III* reprints. Both of the unmodified *Sony* and *Pioneer* units seem to have been created with full FCC compliance in mind.

I could also see several *wired* or *semi-wireless* broadcaster aps that might use a twin lead to route high quality audio all over your plant or whereever. Using wires, you could easily go several hundred feet without running afoul of FCC specs. All the while avoiding the hum and noise problems of using "real" audio. And a whole new world of point-of-sight light modulated FM data links is also newly opened up.

In their intended use, you unplug your car radio antenna, plug in the CD-FM-1, and then reconnect your antenna. A DIN-8 connector goes to your CD player, and the usual red wire to your +12 volt battery.

When your CD gets turned on, its audio appears at 88.1 on your FM dial. All other stations are muted. Which quickly and conveniently can let you use your existing car audio sys- tem without needing anything fancy in the way of rework or switches.

A block diagram of this matchbox
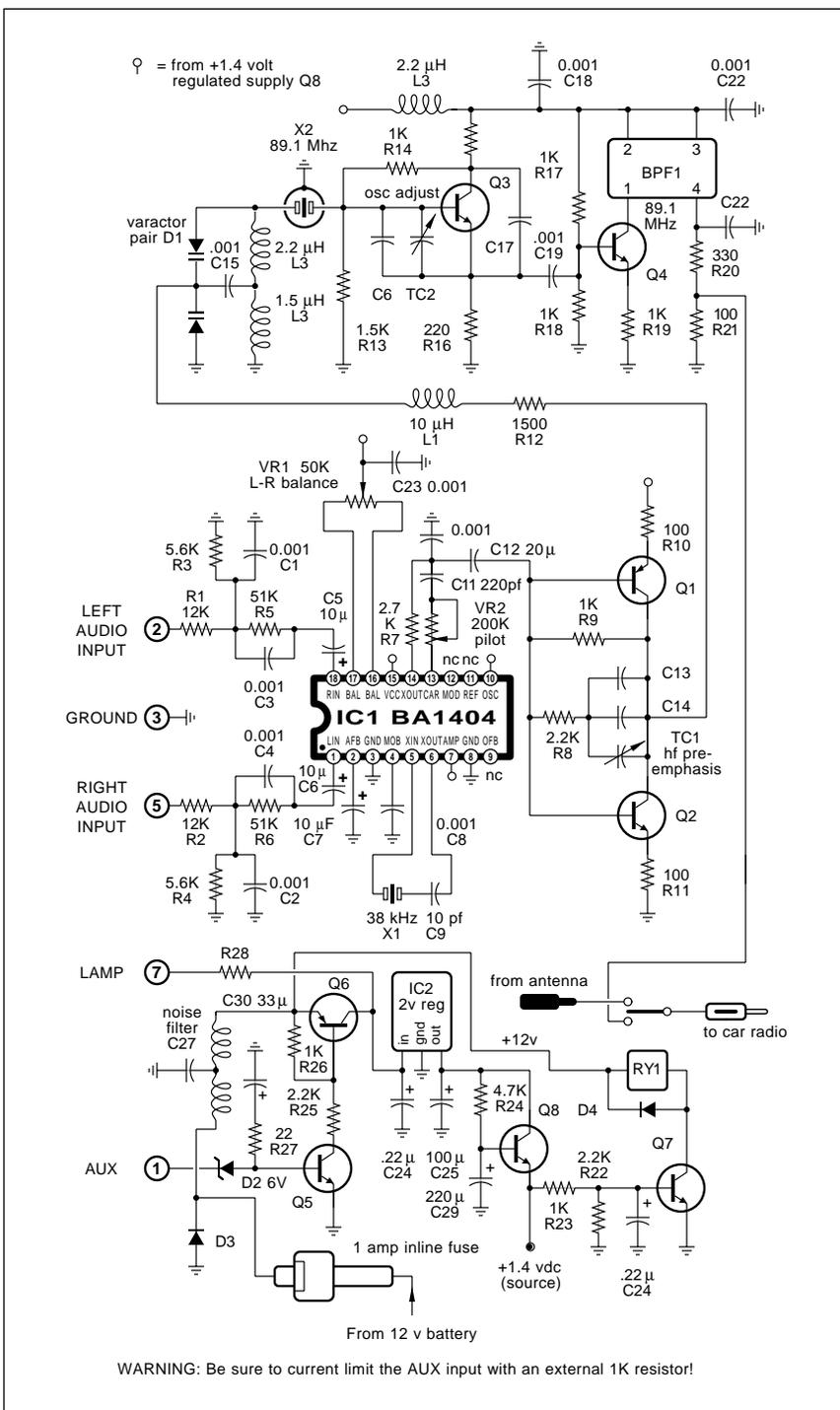
Fig. 3 – APPROXIMATE SCHEMATIC of the Pioneer CD-FM-1. While intended as a CD audio to car radio adaptor, this module can easily become a highly stable and on-channel FM stereo wireless broadcaster. Applying +12 volts to the AUX input activates the module.

sized module appears in figure two, while an approximate and unofficial schematic is shown in figure three. Because of the surface mount parts used, certain component values are only my estimates. The exact circuit shown also may not be fully accurate.

At first glance, this circuit seems deceptively simple. But if you flip the board over, you'll find nearly a dozen more surface mount semiconductors on your foil side. It is obvious that bunches of time and effort went into the design.

As with any circuit, you'll usually want to start off with your power distribution. The twelve volts from the car battery gets turned off and on by an AUX logic signal. The power is only applied when your CD is to be used. The power switching is via input switching field effect transistor Q5 and series power driver Q6. Q6 is followed by a two volt regulator IC2 that in turn is followed by the *dynamic regulator* or *capacitance multiplier* at Q8. The post-regulator will obviously introduce a temperature drift that may or may not be intentional.

Several refinements in the supply switching include zener D2 to prevent any turn-on at all with a weak battery or during cranking; and the network R27-C30 gives a slight turnoff delay to eliminate clicks or thumps.

Except for that switchover relay, the entire rest of the circuit runs on the dynamically regulated 1.4 volt supply. Theoretically, one single AA cell could be used instead.

The heart of the circuit is the great *Rohm* BA-1404 FM stereo broadcaster chip which we have looked at in the *Hardware Hacker II* reprints. Only this time, the internal RF transmitter circuitry is *not* used and gets very carefully deactivated. Left and right audio are combined into the L+R baseband and L-R subcarrier set by that 38 kilohertz X1 crystal pilot 2X reference. Control VR1 adjusts your balance and VR2 sets the 19 kilohertz pilot level.

The multiplexed audio output is resistively added to the pilot and gets routed to a combination driver and preemphasis network using Q1 and Q2. The amount of high frequency preemphasis is adjusted by TC1.

The linear and broadband "crystal puller" is an interesting reactance modulator scheme using a pair of varactor diodes at D1. A simplified circuit of the modulator appears in figure four. What you've got is a crystal put in series with the parallel resonant circuit "A" in turn in series with a second resonant circuit "B".

Tank "A" is tuned well *below* the crystal's parallel resonance and will normally appear as a high *inductive* reactance. Tank "B" is tuned *above* the crystal parallel resonance and should appear as a *capacitive* reactance. In absence of any audio modulation, the reactances will cancel, and the series combination of crystal and the two tanks become a high impedance open circuit. Neat trick.

Those varactor diodes act as electronically variable capacitances that raise or lower the tank frequencies. On the positive modulation swings, both tanks will *increase* their resonant frequencies and vice versa.

Your final result is a reactance frequency modulator whose resonance frequency is set by the crystal but rapidly shiftable either way by the multiplexed audio. Usually, a frequency change varies as the *square root* of a capacitance change. But, because a *pair* of varactor diode capacitors is changing, your resonant frequency changes *linearly* with the modulation input.

At any rate, Q3 is a *Pierce* style oscillator which can oscillate at the frequency determined by the highest impedance sum of the crystal's third overtone resonance and the reactance modulator tanks. 88.1 Megahertz is used in my particular sample, with a final trim given by TC2.

The fundamental crystal frequency is way down at 29.7 Megahertz, but the oscillator tries its best to run at 88.1. The resultant waveform thus has some uneven subharmonic lumps.

It is very important to keep the loading on most any modulated FM oscillator constant. Especially when using an overtone crystal. So, a buffer and driver transistor follows at Q4. This in turn drives a special bandpass filter (probably a surface acoustical wave, or a SAW device) to eliminate any subharmonics and out-of-band harmonics. Only the crystal's third overtone at 88.1 Megahertz is allowed through the filter.

Even with the attenuation through the bandpass filter, the output signal is still too strong to directly couple into any FM receiver's antenna, so it gets further attenuated by R20 and R21.

Recall that supply power is only turned on when you want to listen to your CD player. When the 1.4 vdc supply voltage is present, relay driver Q4 and spike supressor D4 pull in the relay, connecting the rf converted CD audio directly on into your auto radio antenna input. At the same time the antenna is disconnected to prevent any back radiation or unintentional broadcasting. You do, of course, also have to pushbutton select 88.1 Mhz on your car radio for CD audio.

The final **TOTAL IMPEDANCE** of the entire circuit appears as a very high **RESISTANCE** at the instantaneous frequency set by the crystal and by the present audio modulation value.

The third overtone **PARALLEL RESONANCE** of the crystal is at the desired FM channel frequency.

TANK A resonates **ABOVE** the crystal's frequency and appears as a high **INDUCTIVE** reactance.

The **AUDIO MODULATION** uses a pair of **VARACTOR DIODES** to vary these capacitors.

TANK B resonates **BELOW** the crystal's frequency and appears as a high **CAPACITIVE** reactance.

Fig. 4 – SIMPLIFIED SCHEMATIC of the linear reactance modulator.

Once again, this description is for the CD-FM-1. The XA-7A does use a somewhat different circuit that we may look at in a future column.

Hacking the CD-FM-1

In the absence of a CD player, the CD-FM-1 can get activated by connecting the AUX input to the +12 volt supply. Your left and right audio inputs are normally at "line" level; additional gain will be needed for most microphones. Any and all audio connections must be shielded.

The antenna changeover relay may be optionally defeated by shorting R23. Supply current is 30 mils with the relay active and 17 mils with it defeated. Another four mils could be saved by disconnecting your AUX input and shorting collector to emitter on Q6. And nearly another mil by removing R22. The remaining power needed by your "useful" part of the circuit is then 1.4 volts at eleven mils, or around fifteen milliwatts.

With these power reductions, you could probably substitute an ordinary 9 volt "transistor" battery for your 12 volt supply. But do be sure to turn the power off when not in use.

Theoretically, you might want to replace the dynamic regulator Q8 and substitute a single AA cell instead. A bypass cap or two would also be a good idea if you try this. One way or another, though, you can easily get this circuit down into the millipower range. But not micropower.

A possible antenna takeoff point for any low level direct broadcasting experiments seems to be the collector of Q4. Figure five shows how to route a thirty inch antenna wire through a grommet in the case. I got a 50 foot useful range with a good car radio this way. Be sure to insulate the wire tip to prevent possible shorting of the dc supply or damaging the filter. A far cleaner but weaker takeoff point can be the pin 4 filter output.

While the BA1404 supply voltage can be raised as high as three volts, doing so may change the performance of the reactance modulator.

The best way to increase the range is to improve that antenna on your receiver. Be sure to connect a good receiving antenna and disconnect any cable connections. Experiment with the antenna orientation; vertical may be best for car radios and horizontal may be better for home hi-fi.

The range can also be improved by placing a ground plane, such as a grounded cookie sheet (or preferably something bigger), under your transmitter. This could give you a hemi pattern with double field strength.

A directional receiving antenna, such as a correctly cut *Yagi* can also dramatically improve your range.

Note that lower power plus good antenna matching and orientation will give you vastly more range than will high power and poor or improperly aligned antennas.

While there is that extra booster amplifier remaining unused in the BA1404, it might be tricky to access and still remain stable. An external boost circuit could also get built up using a 2N918 transistor or something similar. This would best be done in a separately shielded and a properly decoupled box. *Do not, under any circumstances, attempt to amplify the unfiltered output.* For doing so will create unacceptably strong outband signals. Especially at 29.7 Mhz.

What can you get away with in the way of increased power? Any boost at all gets you into a legal gray area. But, as a practical matter, if your dc input power to your boost stage is under fifty milliwatts, and if nobody ever complains, and if your total useful range is well under a hundred feet, and if you use these yourself rather than selling them to someone else, you can probably get away without any serious problems or hassles.

On the other hand, using one of these as a prediver to broadcast heavy metal to your entire college campus is a very big no-no.

Another Contest or Two

This CD-FM-1 is one of the most hackable projects to come down the pike in a long, long time. For here we have all of the compact and milli-power core circuitry needed for one very high quality and quite stable FM stereo (or mono) broadcaster all in one place and ready to go. With the nasty stuff fully debugged. And one which works just fine with synthesized hi-fi and auto receivers.

For our first contest this month, just tell me about a new or unusual use for a short range and high quality FM stereo or a mono wireless transmitter. Or show me a variation on the circuits we just looked at.

There will be all of those usual *Incredible Secret Money Machine II* book prizes going to the dozen or so best entries. Plus an all-expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all.
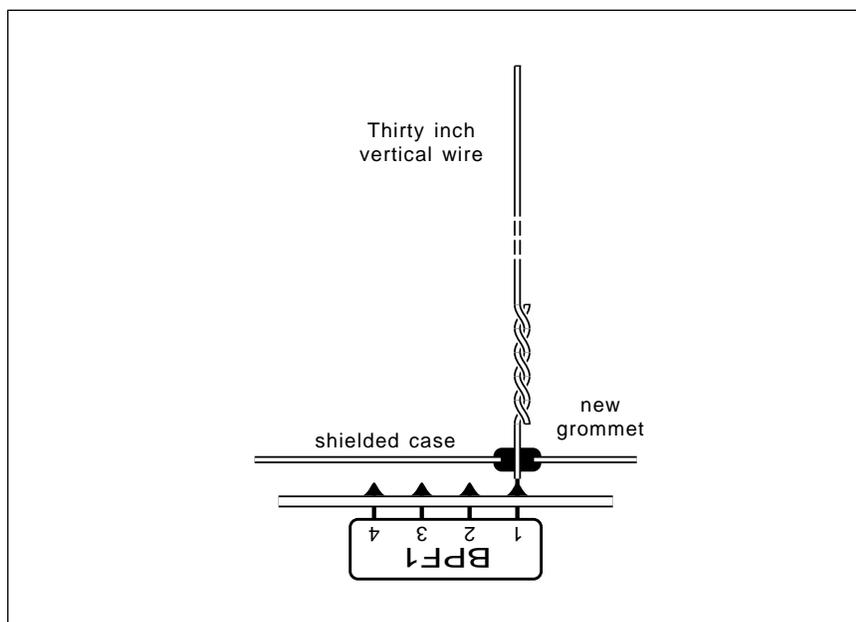
Fig. 5 – AN ANTENNA CAN BE ADDED as shown to the CD-FM-1 for your initial short range FM broadcasting experiments. Be sure to insulate the far end of your coupling gimmick. Experiment to get the best length and orientation.

DYS Resources

I thought we'd do something a tad unusual for our resource sidebar this month. There's a group of direct mail outfits that I will call DYS, short for *Distressed Yuppy Surplus*. All these folks specialize mostly in overpriced toys for the non-technical types. But every once in a while, an electronic gem or two shows up at a really unbeatable price. Or a useful tool. Or a great idea. So it pays to get and stay on their mailing lists.

An example or two: Those "meals in minutes" food vacuum packaging machines seemed to bomb out as a Yuppy prize. Their intended use was to package single portion leftovers so they can be frozen, boiled, or nuked. And they are great for just that. But at $29 each via DYS, these make very effective software and book vacuum packing machines. Be sure to get the type that has the little electric pump with it. Plain old *Baggies* work just fine with these.

Those automated bread machines also bombed at retail. Mostly because far too many females viewed them as an outright threat and throw both the machine and whoever gave it to them out of their house. So I got one via DYS. Around here these days, any bread that is even twenty minutes old is considered "stale", and even the birds won't touch it.

You do have to be selective. For instance, a CPM computer is pretty much worthless at any price. As is any laser printer that does not speak real PostScript. As is any teletext receiver with no teletext to receive.

My three favorite DYS sources are *Dak*, *Comb*, and *Damark*. But every once in a while, a good solution to a technical problem can even be found in such unlikely sources as *Taylor Gifts* or *Harriet Carter*.

I thought I had a lot more of these DYS catalogs than I could find at column deadline time. Is *JS&A* still around? They invented DYS in the first place. How about the *Sharper Image* folks? So why don't you tell me about the rest of them?

As a second contest, just tell me about any non-obvious direct mail resource that can be used to get ideas and solve hacking and other technical problems. Include a sample copy if

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DYS & OTHER RESOURCES

Brookstone
127 Vose Farm Road
Peterborough, NH 03460
(603) 924-9541

Harriet Carter
Stumps Road
North Wayles, PA 19455
(215) 361-5151

Comb Corp
720 Anderson Avenue
St Cloud, MN 56395
(800) 522-3035

Crutchfield
1 Crutchfield Park
Charlottesville, VA 22906
(800) 336-5566

DAK
8200 Remmet Avenue
Canoga Park, CA 91304
(800) DAK-0800

Damark
Box 29900
Minneapolis, MN 55429
(800) 729-9000

47th Street Photo
36 East 19th Street
New York, NY 10003
(800) 221-7774

Harbor Freight
3491 Mission Oaks Blvd
Camarillo, CA 93011
(800) 423-2567

Hello Direct
140 Great Oaks Blvd
San Jose, CA 95119
(800) HI-HELLO

J&R Music World
59-50 Queens-Mid Exway
Maspeth, NY 11378
(800) 221-8180

Micro-Mark
340 Snyder Avenue
Berkeley Heights, NJ 07922
(800) 225-1066

Northern Hydraulics
PO Box 1499
Burnsville, MN 55337
(800) 533-5545

Porter Camera
Box 628
Cedar Falls, IA 50613
(800) 553-2001

Quill
PO Box 50-050
Ontario, CA 91761
(714) 988-3200

Real Goods
966 Mazzoni Street
Ukiah, CA 95482
(800) 762-7325

Tandy Leather
1400 Everman Parkway
Ft Worth, TX 76140
(817) 551-9770

Taylor Gifts
355 East Conestoga Road
Wayne, PA 19087
(215) 789-7007

JC Whitney
1917-19 Archer Avenue
Chicago, IL 60680
(312) 431-6102

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you are able to do so.

I've also added a great heaping bunch of other unusual direct mail sources to our sidebar. While several of these are clearly not DYS, they do offer very interesting and very useful catalogs. And every hacker should definitely know about them.

New Tech Lit

From *Analog Devices*, the fat new *Data Book Volume 10* on their analog integrated circuits. From *WSI*, a new *Programmable Peripherals Design and Applications Handbook* which includes lots of free demo software. From *Intel*, their new *PLD Shell Plus* programmable logic design and its supervision software.

Assorted free samples of *Kydex* thermoplastic sheets are obtainable from *Kleerdex*. This stuff looks great for custom thermoformed cases and enclosures. With lots of colors, thicknesses, and surface finishes. And free tactile dome keyswitch samples are available through *Snaptron*. Finally, *Avery Dennison* now has test fixture samples of their *FasTape UHA* super strong clear adhesives.

A reminder that I still have lots of Book-on-demand bound reprint sets available on pretty near all of my recent columns. Included are *Ask the Guru* I, II, and III, *Hardware Hacker* II and III, *LaserWriter Secrets*, and *Blatant Opportunist*. Write or call me for more details. ✦

Don Lancaster's
Hardware Hacker

June, 1992

Uh whoops. On back in that pc layout for the sync stripper and universal video interface (RE April 92 page 65, Fig 2), it seems one of my last minute layout "improvements" left one extra trace from pin 9 to that SYNC output line. Sorry about that. If you have already etched your board, just cut this tiny run out.

Figure one is correct, and the layout shown in these reprints has also been fixed.

Moral: It is always the things that you *thought* you triple checked that are certain to return to haunt you.

We will see several other possible changes to the sync stripper in just a moment when we look at some new *Neo-Geo* interface ideas below.

An update to the crystal stabilized FM stereo broadcaster circuit that we looked at last month: I've now had a brief chance to check into that new *Sony* XA7A unit. While it uses pretty much the same circuit we did look at, it seems more costly, klutzier, and far harder to hack.

The BA1404 uses a surface mount. There's some tight and tiny shields, and some awkward "3-D" component arrangements. *Sony* appears to be getting two channels by pulling their crystal an astounding 200 kilohertz in either direction. I'd bet their stability isn't as good as a *Pioneer* CD-FM-1.

Speaking of which, it should be possible to significantly improve the CD-FM-1 range by replacing the SAW filter load used by Q4 with a simple tapped resonant tank located *outside* of your existing shield. This would switch Q4 from class A over to class C operation. Some bypassing on R19 could also help, as might lowering its value somewhat.

More details when I get a chance. Meanwhile, do let me know what you come up with on your own.

Patents Again

The morning mail had yet another sad example of a hardware hacker done in by the patent system. Or more correctly, done in by the outlandish popular myths and all the gross misconceptions surrounding patenting. One more time: *Any hardware hacker based small-scale involvement in the patent system is absolutely certain to result in the net loss of time, energy, money, and sanity.* Your state lottery is a vastly better investment.

This example involved an Oregon inventor who sent me a copy of his new patent and asked for my help in marketing it. The patent is intended to recover electrical energy from a steam line by impinging the steam onto a piezoelectric generator. The patentee admitted he lived in a very "remote area" where all research was difficult.

And he did specifically ask me for comments, so here goes…

Well, it must have been my kind of remote area. There was obviously no telephone available to call the *Dialog Information Service*, and no postal or UPS service to receive *UMI* reprints. Their local library had to be so small that they had no *Uhlricht's Periodical's Dictionary* which included the EPRI *Electric Power Research Institute Journal*.

And, of course, no *Encyclopedia of Associations* which would include the *Association of Energy Engineers* with their great conference publications on this type of cogeneration device.

I felt the patent was rather weak. I think I could personally find all kinds of prior art way back in the 1890-1930 time frame. And I do think the idea would be so totally obvious to any "practitioner in the field" that prior art would not even be required to quickly bust this patent. In fact, attempting to defend it could easily lead to a nasty old frivolous litigation countersuit.

"Outside of that Missus Lincoln, how was the play?" Well, I just don't know of any higher power electricity-producing piezo generators. Piezo tends to be grossly inefficient and involves frequencies and impedance levels that are hard to elegantly deal with at higher power. These tend to have lousy power factors, since piezo transducers are often very capacitive. Their optimum working temperatures are well below that of live steam.

Further, we obviously have a heat engine here that has to obey the laws of thermodynamics. The best possible efficiency (also known as the *Carnot* efficiency) would end up rather low. Which is why we don't have too many
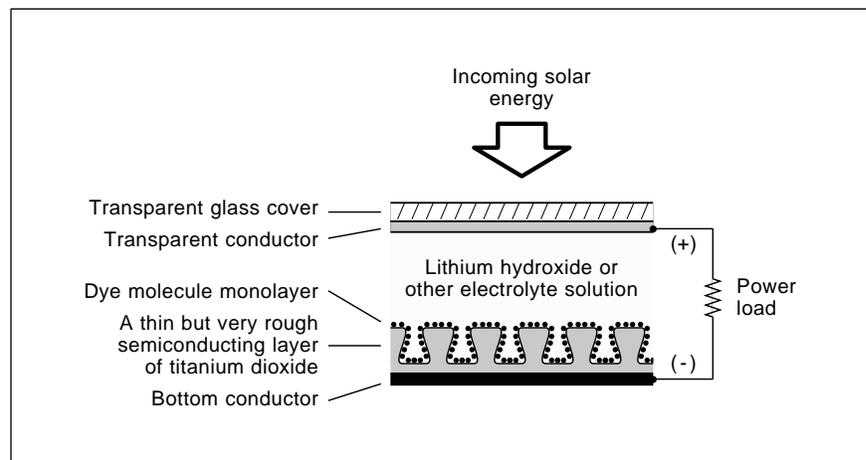
Fig. 1 – ANOTHER SOLAR BREAKTHROUGH? The dye-based solar method uses a large area monolayer of individual dye molecules to act as optical antennas and rectifiers. An electron "borrowed" from the electrolyte by the dye gets its energy level raised by an incoming photon, jumps the rectifying semiconductor gap, delivers useful load power, and then returns to the electrolyte. The high efficiency process is related to the first stage of plant photosynthesis. All the materials used are cheap and fairly low tech.

steam engines these days. And I feel the P-V (pressure-volume) diagram for the new proposed impingement system would be absurdly far away from the best possible. It is clearly not at all adiabatic.

I would be quite surprised if the overall electrical recovery efficiency could ever exceed 0.1 percent. Thus, I feel this product would *never* be able to pay for itself or for the time value of the money used. Let alone recover any useful power.

So, I'd guess my answer on any marketing of this product would be "Uh, to whom?"

Now, there are all sorts of exciting steam recovery developments going on. These do involve *bottoming* and *scavenging* cycles and may use exotic fluids other than water vapor. And they are revolutionizing commercial electric power production by sharply improved efficiencies. And the pulse combustion furnace folks are playing lots of neat games in super efficient *latent heat* (gas to liquid) recovery. So there are bunches of new possible opportunities in this area. Some of them eminently hackable.

By the way, one ancient but quite readable book on thermodynamics is Sanford's *Heat Engines*, found in the *Doubleday Science Series*. No hacker can afford to ignore the fundamental laws of thermodynamics.

Where to go from here? First and foremost *avoid any and all involvements with the patent system in any way, shape, or form.*

Do so religiously.

Second, get yourself a fresh copy of *The Case Against Patents*, either in my *Blatant Opportunist* reprints or as our *GEnie* tutorial PSRT textfile #162 NOPATENT.TXT. Rumor has it that this reprint may also shortly appear in the *Whole Earth Review*.

Third, there is a unique magazine known as *Midnight Engineering* that specifically supports the small scale developers, product prototypers, and startups. Giving proven and realistic help. Free samples on request.

Inventing, of course, is a highly reprehensible and incurably addictive social disease. One that is simply not talked about in polite company. So, fourth and finally, you may want to join some AA type support group. A typical example group would be the *Zimmer Foundation*, associated with the *Michigan Inventor's Council*. Just be certain your selected group isn't a marketing scam in disguise.

Another Solar Breakthrough?

Lots of credibility has been newly given to *dye methods* of solar energy conversion. As we have seen in past issues, certain dye molecules can act as both an antenna and rectifier, converting any incoming photons into an electron current. The dye method is potentially very cheap, very efficient, and should end up quite easy to mass produce. Only low cost and low tech materials are involved.

Do check out the October 24, 1991 issue of *Nature*. (vol 353 #6346). Especially Thomas Mallouk's *Bettering nature's solar cells* (on pages 698-99)

and also Brian O'Regan and Michael Gratzel's *A low-cost high-efficiency solar cell based upon dye-sensitized collodial titanium dioxide films* (on pages 737-739).

Some librarians appear to have lots of trouble finding *Nature*, possibly because it is British. Which is a real mystery, since *Nature* is regarded by most of those in the know as the finest and most significant science journal anywhere in the world.

Obviously, any magazine that gets on up to weekly issue #6346 must be doing something right. If you get any static picking up any *Nature* copies locally, scream and holler and stamp your feet. Or use the address found in our *Names & Numbers* sidebar.

Figure one shows you the general idea behind any dye-based solar cell. The cell uses liquids and is related to a wet cell battery. An electrolyte of a lithium salt or something similar gets used. The uppermost terminal is a conductive metal film under a clear glass. The bottom terminal is also a conductive metal film. Onto this film, a very thin and very rough layer of a titanium dioxide semiconductor gets deposited. Together these can form a metal barrier diode.

The semiconductor film is made as rough as possible to greatly increase its surface area. The current effective areas are in the 2000:1 range. A one molecule thin *monolayer* of *trimetric ruthenium* dye then gets deposited on the semiconductor surface.

The single dye molecules can act as both an antenna and a rectifier. An existing electron in your electrolyte solution will have its energy level increased by the incoming optical photons. These high energy electrons jump the semiconductor junction, go on through the load delivering useful power, and return via your top electrode, creating a self-rectifying and light induced photocurrent.

So far, the actual efficiencies are only slightly better than poly silicon cells. But all of the materials are far cheaper (titanium dioxide is used to make white house paint; only small amounts of dye are used). They also lend themselves to larger area, high volume processing.

The theoretical efficiencies of dye based systems are quite high. There are plenty of potential directions for
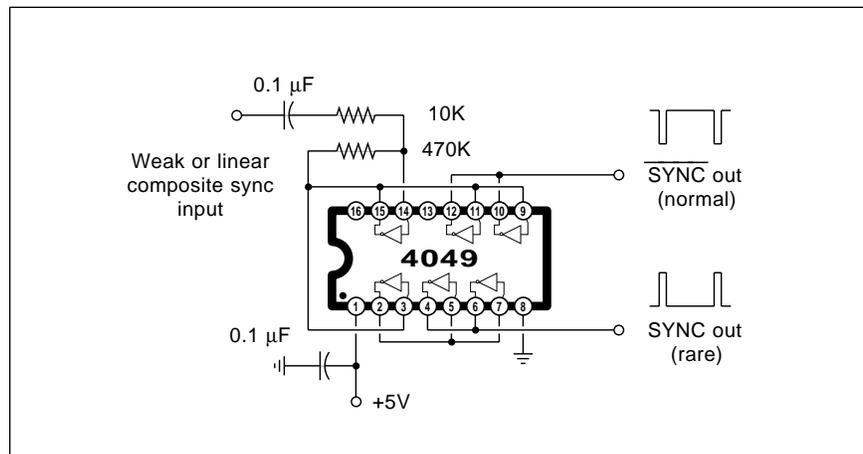
Fig. 2 – THIS SYNC AMPLIFIER can take "linear" or "weak" RGB composite sync signals and make them CMOS and/or TTL compatible. It also gives you an optional and rarely needed active high sync output.

ongoing improvements. And the long term durability looks good.

There are several remarkable similarities between dye-based solar and plant photosynthesis. In fact, the biggest difference is that dye-based solar stops with generated electrons, while photosynthesis will go on and use the high energy electrons to drive the intermediate chemical reactions which can ultimately create sugars, cellulose, and other tasty stuff.

Dye based solar is already more efficient than the best that today's plants can do; On the other hand, the plants can create and fix themselves at very low costs.

More on this as the drama unfolds. But, from here, it does seem like dye based solar has the potential to end up as a real winner.

RGB Video Fundamentals

I have recently been working with Dennis Carper of *Redmond Cable* in interfacing all sorts of video games to all types of leftover surplus computer monitors. So, I guess it might be a good time to review some of the fundamentals of RGB monitors.

The reasons we go to the separate *red-green-blue* route in the first place are for *picture quality* and for *picture resolution*. Regardless of how much trouble you go to, it is simply not possible to glomp onto the antenna terminals of an ordinary tv set and display anything even *remotely* near what is needed as a bare minimum for all of today's color computer displays or premium arcade video games. The needed bandwidths and scan rates are simply not there.

Unlike broadcast signals (such as NTSC or PAL or SECAM), there are *no* universal standards being used for RGB monitors. If it has three separate video lines on it, it is an RGB system. Period. Thus, you will have to be *very* careful what your video source and your video monitor are capable of before you try to connect them.

The simplest of RGB systems use "TTL" monitors. These do not accept video as such. Instead, they receive digital logic signals which turn their red, green, and blue beams *entirely* off or on. Thus you can only get *eight* possible colors. All eight of which are *always* fully saturated. Some TTL monitors include a fourth *brightness*

line that gives you a choice of "full" or "half" bright, upping the apparent color total to sixteen.

Instead, on a *linear* RGB monitor, all shades of all colors are possible. Linear monitors need much more in the areas of video amplification and linearization (or *gamma correction*) circuits. Obviously, linear monitors are required for "real" video from a cable or broadcast source, or anytime else you need a very wide range of hue and saturation values.

Most linear monitors are not too fussy over accepting *interlaced* scans, as get used on standard tv; or the *non-interlaced* scans, as *must* get used on most data displays.

But linear monitors are extremely fussy over their *horizontal scan rates*. Ordinary tv uses the horizontal scan rate of 15.735 kilohertz for color or 15.750 kilohertz for black and white. Most computer scan rates are double this, up in the 32 kilohertz range. And

premium systems can have scan rates of 80 kilohertz or higher.

Unless your monitor is carefully designed to be a *multisyncing* type, it will only accept a *very* limited horizontal scan rate range. Thus, *there is no way you could use an ordinary broadcast RGB monitor to display a Mac or VGA output*. It flat out can not operate at the higher scan rates.

One of the ruder surprises to Apple IIgs people downgrading to a Mac LC is that their old color monitor will no longer work. Their IIgs monitor is a broadcast-only style, while those LC video scan rates are on up in the 30 kilohertz range. Fortunately, a simple jumpering option (which we saw a few columns back) lets the LC use an ordinary and cheaper VGA monitor.

Thus, *you have to be sure that your intended RGB monitor is capable of accepting the horizontal scan rates provided by your video source*. Some combinations simply will not work.

8 | BLUE VIDEO
For linear RGB monitor use. One volt peak-to-peak gets internally capacitor coupled.

7 | /RGB SYNC
For linear RGB monitor use. Active low combined vertical and horizontal sync pulses.

1 volt capacitor coupled source is not CMOS/TTL compatable and may need amplification.

Neo-Geo AV/out rear panel female

3 | NTSC VIDEO
Plain old NTSC composite video appears on this line. The sync tips are at ground.

One volt peak to peak into a 75Ω load. Internally capacitor coupled.

5 | GREEN VIDEO
For linear RGB monitor use. One volt peak-to-peak gets internally capacitor coupled.

6 | RED VIDEO
For linear RGB monitor use. One volt peak-to-peak gets internally capacitor coupled.

1 | MONO SOUND
The monophonic sound output appears on this pin.

One volt peak is suitable for amplifiers but not headphones. Use separate shielded cable.

Use standard DIN-8 male connector

4 | +5 VOLTS DC
A limited amount of +5 volts supply power may be drawn out of this pin for sync amplifiers.

Limit current to 50 milliamperes and use thorough bypassing.

2 | GROUND
Used for all cable shields, video return, and any sync amplifier grounding.

Fig. 3 – THE NEO-GEO AV-OUT rear connector has both NTSC and RGB output pins available. Here are the key details.

A final major consideration is the monitor's *resolution*. The resolution is set by the video bandwidth and the pitch of the color bars or dots on the screen. Images will smear if you try to view them on any monitor whose resolution is too low for the intended application. The results can end up anywhere from a slight eyestrain to totally unviewable.

So, a second rule: *Make absolutely certain you test and use any monitor in its intended final use before you actually pay for it.*

Your video lines could be *high impedance* cables if the runs are short, or *terminated* ones (usually 75 ohms) for longer distances. A fair amount of power is required to properly drive a terminated video cable. *Maxim* is one good source for video drivers. Video cables are best done either as fully shielded, or, at the least, as twisted pairs. If any separate grounds are provided, they should be used as they were intended.

If your video source has any dc offset present (such as the emitter follower outputs of a *Super Nintendo*, then you *must* provide for a capacitor coupling between your source and the monitor. Very large capacitors are recommended, of at least 220 microfarads or more. But these may already be built in, so check first.

There are several synchronizing options used in RGB systems. Some systems tack sync signals onto the green channel and later strip them off. But most systems have separate sync line(s) which deliver the horizontal, vertical, or composite sync signals.

To further confuse matters, sync lines can be smaller one volt signals at analog levels, or can be TTL or CMOS compatible. Others may be at TTL levels, but end up too small for CMOS and too weak for TTL. We saw a *Super Nintendo* workaround for this last month using a simple 680 ohm resistor to ground.

Typical sync lines are *active low* meaning that your sync tips are at ground. But a few (especially earlier *Commodore* products) demand an *active high* composite sync.

Figure two shows you how to use several inverters to amplify low level sync signals into full CMOS and TTL compatibility having your choice of either active low or active high sync tips. Your first stage can be a biased inverter amplifier having a gain of twenty or more. The second inverter further cleans up your now-digital waveform, while the third and fourth stages act as inverters or drivers.

If you try this linear amplifier stunt with other CMOS gates or inverters, be sure to use "single stage" unbuf- fered (UB) versions; other buffered ones may have too much gain and could oscillate. More details in my *CMOS Cookbook*.

Our sync separator and universal video interface from two months back is easily modified to provide suitable sync amplification for the Neo-Geo or Super Nintendo.

Sound is separately dealt with on a RGB system. Sometimes, there will be no sound at all. One clue here is the absence of any volume control. *Radio Shack* makes a neat little $11 lab amplifier that can sit in for you. Other options are monophonic sound, stereo sound, or a *multiplexed stereo sound* accepting R + L and R - L inputs. Super Nintendo uses multiplexed sound.

If you forget to demultiplex, one channel will sound monophonic, and the other might sound awfully tinny and just plain "wrong". To properly demultiplex, you *add* the two signals together to get the right channel and *subtract* them to get the left one.

Regardless of your sound system, *totally shielded audio cables are a must.* Ideally, they should be *totally* separate from all your video cables, owing to the strong "hum" and "buzz" induced by vertical rate signals.

So, what can you interface to who? Use your oscilloscope to view all the normal outputs of your video source run in their intended way. Then do the same for the "normal" inputs to the monitor.

Some hints: To tell if a source is capacitor coupled, briefly connect a 470 ohm resistor between the pin and ground or +5. If the scope display bounces around and slowly drifts on back, you are ac capacitor coupled. If it remains in the initial position (or possibly gets slightly smaller), then you are dc coupled. Be sure to note any fixed offset voltage.

To find out your source impedance, note that any resistive load *equal* to your source impedance will drop your output signal level to *one half* of the open circuit value.

Neo-Geo Interface Ideas

Sorry, but our renowned panel of experts (the munchkin division of *Special Editions*) were not at all impressed with the new *Neo Geo* game system. Their preference for *Super Nintendo* was totally overwhelming, and I will certainly defer to their expertise. But, if you happen to like the Neo Geo system, figure three can show you the rear *A/V out* interface connector pinouts.

There are several interesting interface options here. Present are the usual NTSC composite video line on pin 3, a ground on pin 2, and a +5 volt supply on pin 4. You could use this supply for such low current needs as modulators or sync amplifiers. For
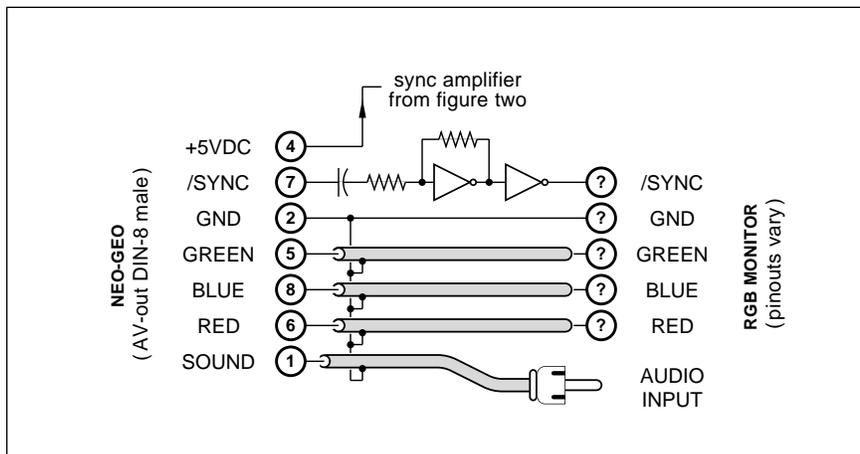
Fig. 4 – TYPICAL NEO-GEO RGB INTERFACE connections. The details and pinouts vary with your choice of monitor. The sync amplifier shown may or may not be needed. Custom cables and kits are available from Redmond Cable.

RGB use, there is a red line on pin 6, a green line on pin 5, and the blue line on pin 8. These are capacitor coupled video from a 70 ohm source.

Their RGB active low sync line appears on pin 7. It is also in the form of capacitor coupled video at a one volt amplitude. Thus, the sync line is *not* presently TTL/CMOS logic compatible, and you may need to use the sync amplifier of figure two.

Figure four shows you a baseline RGB interface for the *Neo-Geo*. The connector is a standard DIN-8 that is *Radio Shack* stock. As with our previous *Super Nintendo* interface, stock and custom cables, connectors, and any and all individual parts are obtainable through *Redmond Cable*.

Surplus Resources

As our resource sidebar for this month, I decided I would gather together what I feel are only the best of the very best in hacker surplus stores. These are the ones I have used consistently over the years and can personally recommend.

The best surplus store anywhere, of course, is *Jerryco*, who've recently become *American Science & Surplus*. They are strong in electromechanical parts and unusual materials.

The highest profile surplus outfit is *Edmund Scientific* who are really useful for magnets and optics.

For genuine World War II vintage surplus, *Fair Radio Sales* is the preeminent place to go. For heavier iron stuff, especially motors, steppers or hydraulics, try either *C&H Sales* or *Burden's Surplus Center*. And for the best prices on a wide variety of components, try *Surplus Traders*.

Several other outfits I have found useful include *Herbach and Rademan* (infrared people detectors), *Marlin Jones* (power supplies and steppers), *Circuit Specialists* (for harder-to-find hacker integrated circuits), *Time Line* (solid state imaging chips), and either *All Electronics* or *R&D Electronics* (generally good electronic buys).

Finally, for totally outlandish plain old weird stuff, *Archie McPhee* is it claws down. Where else can you get a three foot rubber iguana?

These are just my own personal selections, and I am sure you have your own favorites as well. But why don't you tell me instead?

ELECTRONIC SURPLUS RESOURCES

All Electronics Corp.
PO Box 567
Van Nuys, CA 91408
(800) 826-5432

American Science & Surplus
601 Linden Place
Evanston, IL 60202
(708) 475-8440

C & H Sales
PO Box 5356
Pasadena, CA 91117
(800) 325-9465

Circuit Specialists
PO Box 3047
Scottsdale, AZ 85271
(800) 528-1417

Edmund Scientific
101 E. Gloucester Pike
Barrington, NJ 08007
(609) 573-6250

Fair Radio Sales
PO Box 1105
Lima, OH 45802
(419) 227-6573

Herbach and Rademan
18 Canal Street
Bristol, PA 19007
(215) 788-5583

Marlin P. Jones & Assoc.
PO Box 12685
Lake Park, FL 33403
(407) 848-8236

Archie McPhee
PO Box 30852
Seattle, WA 98103
(206) 547-2467

R & D Electronics
1224 Prospect Avenue
Cleveland, OH 44115
(216) 621-1121

Surplus Center
PO Box 82209
Lincoln, NE 68501
(800) 488-3407

Surplus Traders
PO Box 276
Alburg, VT 05440
(514) 739-9328

For our contest this month, just tell me about your favorite surplus or any other hacker-friendly and reasonably priced source of supply for unusual goodies. There will be several of my *Incredible Secret Money Machine II* book prizes, plus an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the best of all.

If possible, include a catalog or put me on their mailing list. Be sure to send your *written* entries directly to me here at *Synergetics* rather than on over to **Radio-Electronics** editorial.

New Tech Lit

The *Ashtech* folks now offer some really great and reasonably priced ($100) four-day courses on those GPS navigation systems, besides offering bunches of free ap notes.

From *OKI Semiconductor*, some *speech application notes* on the solid state speech synthesis chips.

The *Micro-Avionics Newsletter* is a brand new and sorely needed labor-of-love hacker pub that focuses on the remote controls, navigation, auto-piloting and the television links used on low end and amateur radio controlled R/C models and other aerial

platforms. Sample issues are $5.

Another very interesting magazine is *Lighting Dimensions*, a slick and well-done publication intended for the stage, theater, television, and rock concert lighting specialists.

It's been a while since I mentioned the *Society for Optical Engineering*. Their freebie *SPIE Technical Publications* lists all sorts of unique books and reprints on such goodies as solid state gyros, high speed photography, robot vision, lasers, liquid crystals, and even on *binary optics*, a stunning and revolutionary new field that I hope to eventually cover.

There are several exciting new developments in hacker printed circuits these days. The *Kepro* folks now offer a new *How to make printed circuit boards* booklet. A product called PCBTF-1000 is a brand new transfer film for that direct toner method, newly available by way of *Techniks Incorporated*.

And I've just posted my shareware printed circuit circuit layout package over to *GEnie* PSRT as our file #401 PRNCRCT.GPS. Plus our summary tutorial on new hacker printed circuit techniques as file #419 NUTS3.PS. ❖

Don Lancaster's
Hardware Hacker

August, 1992

A quickie update before we begin: We've found out that most of those popular FM wireless broadcaster circuits will no longer work because nearly all of the newer synthesized receivers positively *demand* exactly on-channel frequencies. In recent columns, we've seen how that *Pioneer* CD-FM-1 can easily be modified into a fine crystal controlled FM stereo broadcaster.

At the time, I didn't really believe that a plain old third overtone crystal could really get pulled that far and still provide a CD quality result. So, I asked an outstanding VCXO designer by the name of Jim FitzSimons to do a circuit analysis for me. The bottom line: Yes, you can pull an ordinary third overtone crystal far enough and linearly enough to do the job.

Some other fallout from the VCXO analysis: The temp comped 1.4 volt supply is quite critical for linearity, and you should *not* try and raise this voltage. And the varactor modulator does its work by shifting the *series* resonant point of the crystal.

Electronic Correlation

This is one topic that can get real hairy fast, but let us try it anyhow. Many fancier electronic applications need *correlation* techniques of one sort or another. A few of the zillions of possible examples include spread spectrum communications, machine vision, radar, GPS navigation, speech recognition, video compression, radio astronomy, planetary probes, fuzzy logic, pattern recognition, etc…

Well, correlation is simply *looking for a match*. A match against some original signal. Or any replica of that signal. Or against some expected pattern. And the longer you look for your match, the deeper the noise you can extract it from. With luck and a decent correlator, all your noise and interfering signals will cancel out or, at the least, pile up far more slowly. As a general rule, if any electronic system has to push the limits of what can be done, correlation often will end up playing a big role.

A trivially simple ferinstance of correlation is the Morse Code. You or some machine receive a pattern of short-long-short-short. You can then compare that pattern against a stored list of all of the acceptable characters and numbers. A beginner might note "That sounds like "li-no-le-um" and linoleum starts with an "L". With practice, you can do a near immediate correlation, rather than having to go and compare each and every possible pattern. You simply "hear" the code as letters, in the same way a musician "sees" notes. But, inside your brain, a wetware correlation is happening.

Let's see how correlation can help push the detection limits of a simple problem. Say you have a very long driveway and want to know whenever anyone shows up. You put a bright LED on one post and a photocell on the other and build an "electric eye". And it works just fine at night.

But when the sun comes up, the photocell saturates and nothing seems to work. You next try some obvious non-correlation cures to see if they help. You raise the LED power, add a deep red filter and some focusing optics to improve your signal and reduce the noise. You amplify only those received signal changes that are in the expected frequency range of a passing car. And you even use some sort of AGC loop to keep the sensed light in the linear detector range.

Any of these stunts should work in a plain old driveway sensor, but let's pretend that, after trying everything you could think of to improve your linearity, noise rejection, and signal to noise ratio, that things still aren't quite reliable enough. Now what?

Figure one shows you one of the oldest and simplest of the electronic correlation techniques. It is called a *synchronous demodulator*, and may still even go by its ancient name of a *lock-in amplifier*. You chop your LED at an audio rate, turning it on and off at, maybe, 1000 times a second. You design a receiver that only amplifies signals near 1000 Hertz.

Now for the tricky part. Instead of just detecting your 1000 Hertz, you *take a copy of your original signal* and route that to a demodulator that obeys "amplify when I'm positive,; amplify AND INVERT when I'm negative".

Well, neglecting any phase shifts or delays (these can be easily gotten around), your real received signal will *always* match your signal copy, and it should nicely pile up. But any interfering signals will sometimes add and sometimes subtract. So, most interference cancels.

By correlating, or *looking for an exact match for an expected input signal*, you have quite dramatically improved your ability to reject nearly all types of potential interference.

You can also view a synchronous
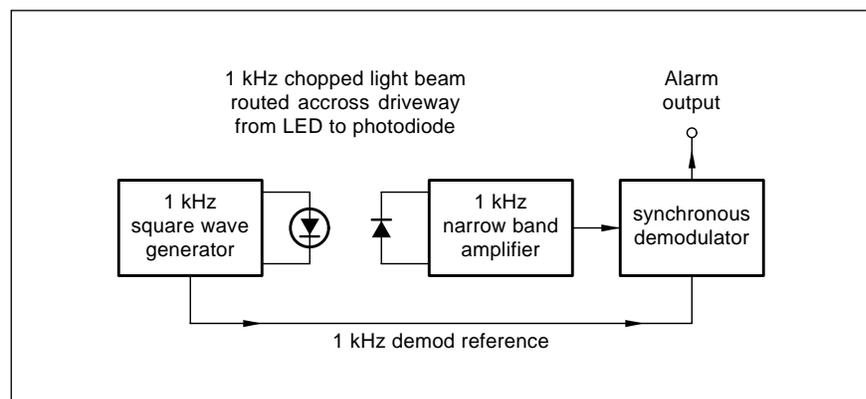
Fig. 1 – A "LOCK-IN AMPLIFIER", or synchronous demodulator is an older and simpler example of electronic correlation. In this driveway detector, the desired "no cars" signal can easily be extracted from sunlight or other interference.

demodulator as an extremely narrow bandpass filter that automatically and exactly tracks your input signal. Even if your input signal is varying. But synchronous demodulation goes one step further than a simple filter. Note that signals of the wrong phase get more or less rejected. For instance, any interfering signal that happens to be at a phase angle of plus or minus 90 degrees get *completely* rejected.

Go through the math, and you'll find that a sync demod offers a "free" additional *three decibels* of signal to noise ratio improvement over the best detector you can come up with that does not use correlation. And three decibels at or near a digital detection threshold can mean a big world of difference in reliability. From errors per second to errors per hour.

Building a Correlator

In general, you do a correlation by *multiplying* and then by *adding*. You first find how well a smaller piece of your received signal can match. You might assign a +1 for "agree" and a -1 for "disagree". Then you add up (or *integrate*) each individual agreement or disagreement to get some overall total. The summed total is called your *correlation coefficient*. If your final correlation coefficient ends up high enough, you vote "yes". Or else you simply pass the correlation value on to more circuitry that wants to know relative results.

Correlation can be done by using analog, digital, or mixed signals. In the digital world, you can correlate in either a serial or parallel mode. Serial is slow and low in cost, while parallel is fast and complex. But serial may not be nearly fast enough for many real-world uses. A special class of microprocessors we know as *digital signal processors* are arranged to do many correlation techniques faster and easier than regular CPU chips.

Several simple correlator circuits are shown in figure two. For linear circuits, a diode bridge or any four quadrant multiplier should work just fine. For high frequency RF work, the *Signetics* NE605 is a great choice.

But my favorite lower frequency linear sync demod is the gated gain amplifier of 1A. If the *mask* signal is low, the gain is **plus one**. If it is high then the gain is **minus one**. This is a synchronous full wave rectifier that does all of the multiplying for us. A following *integration* stage will do the addition for us. Often the addition can be done with a RC network.

The fundamental digital correlation circuit is the *compare* gate, otherwise known as an *exclusive NOR*. This is shown in figure 2-B. A compare gate gives you a one out if the inputs are *identical* and a zero out if they are *different*. For serial use, one compare gate can be followed by an up-down counter. For parallel use, bunches of compare gates are followed by a special pile of adders configured as a "how many ones are in this word?" circuit. Figure 2C shows details.

Yes, you can go out and buy digital correlator chips, but they do tend to be specialized and expensive. *TRW* and *Stanford Telecomm* are two big sources. A second more popular route is to use firmware and a digital signal processing chip.

On your own, you can easily and cheaply hack up an eight bit digital correlator out of any plain jane 2764 EPROM, following the details from figure 2D. Your truth table simply answers the question "How many bits match?" The answer will be a four bit word ranging from -8 to +8.

For any sixteen bit parallel digital correlator, simply precede a different 2716 EPROM with quad EXOR gates.

Correlation could also be done in software. For instance, in PostScript, just do an *eor not* sequence, followed by a "number of ones" table lookup.

Correlation Functions

An exact match against your initial signal is called an *autocorrelation*. Attempting a match against anything else is a *crosscorrelation*. Should you try a match against some shifted or delayed version of your initial signal, you're doing a *shifted autocorrelation*.

Ideally, your autocorrelations will always strongly agree, and most of your crosscorrelations will more or less cancel to zero. But those shifted autocorrelations get interesting in a

(A) An analog correlator using a "plus or minus one" amplifier.

(B) Serial digital correlator uses an exclusive-NOR gate.

(C) Parallel digital correlator uses gates and a special adder.

(D) 2764 EPROM made into a parallel 8-bit correlator.
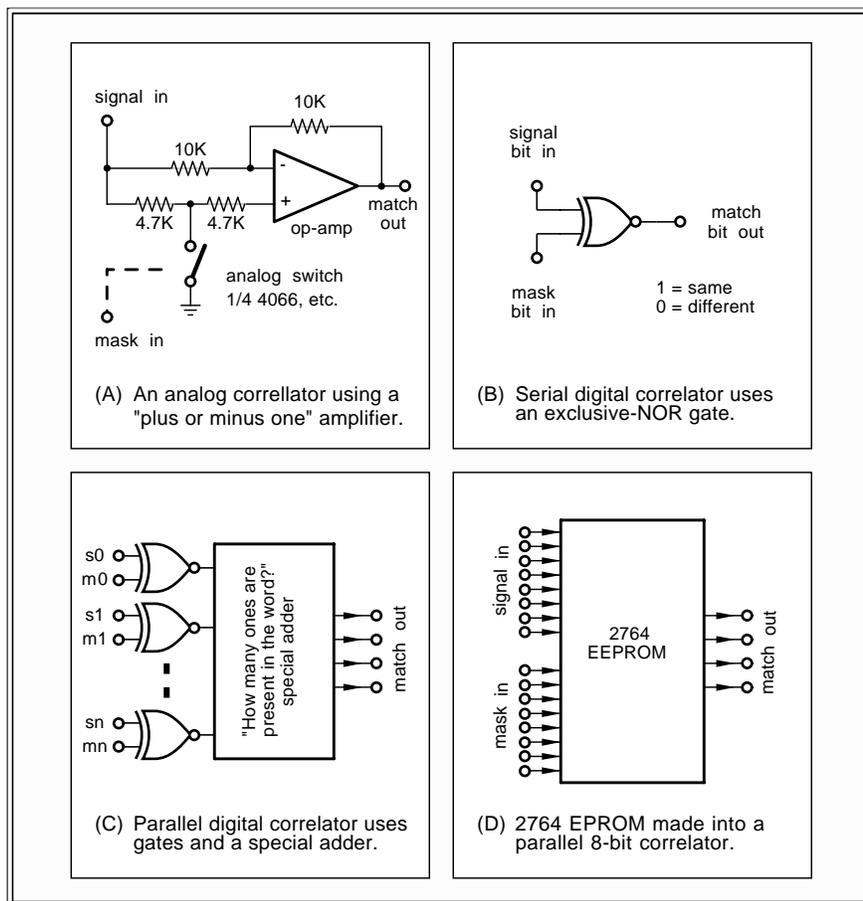
Fig. 2 – HERE ARE FOUR POPULAR METHODS to do electronic correllations.

very big hurry.

For instance, say you now have a planetary probe flying past Neptune. The extension cord needed to deliver an exact copy of your autocorrelation signal tends to end up a tad on the longish side. Not to mention asteroid breakage. The trick, instead, is to take a local shifted autocorrelation signal and move it around until you get a strong match to your incoming data. This is called *acquiring a lock*. Until you have your local clone reference precisely locked to the incoming data, you can't receive any useful info.

By far the most unusually unique autocorrelation function occurs with the sequence 1000. Like so…

```
    1 0 0 0
    1 0 0 0
    =========
  +1 +1 +1 +1 ----> 4

    1 0 0 0
    0 1 0 0
    =========
  -1 -1 +1 +1 ----> 0

    1 0 0 0
    0 0 1 0
    =========
  -1 +1 -1 +1 ----> 0

    1 0 0 0
    0 0 0 1
    =========
  -1 +1 +1 -1 ----> 0
```

Here we are *not* adding. We are comparing two *vertical* bits at a time, and putting down a "+1" if they are identical and a "-1" when they are different. Only then do you add up the total results. Note that the second, third, and fourth examples represent shifts of one, two, and three bits in your target word. Amazingly, all of the shifted autocorrelation results are precisely zero!

Very sadly, this is the *only* known digital sequence that gives a "perfect" shifted autocorrelation. The longer codes will do all sorts of weird things with the shifted summations. Most of which can end up as less than useless. Some of the more interesting (and more useful) shorter autocorrelation codes are shown you in figure three.

There are far fewer autocorrelation functions than there are possible bit combinations in any word. Why? Because shifted bit patterns, mirror patterns, and complementary patterns will all end up generating identical autocorrelation functions.

The best possible autocorrelation codes are called *Barker Codes*. Sadly, these are all short and are few and far between. Instead, when you are using a long correlation code, you'll often have to settle for one that is simply "well behaved".

On any longer digital codes, most cross correlation values will be very low. For any code length, you could easily predict how badly a random interfering noise code might cross correlate. Just use a messy piece of mathematics known as the *bionomial coefficients*. For instance, on a fairly short code of 20 bits, only *one* cross correlation will total to +20 and one other to -20. A mere twenty will sum to a value of +18.

Why twenty? Because there are only twenty possible places in a 20-bit word for the one bit errors. How many possible errors of two bits? Go through the bionomial math and the answer is a scant 190 cases that sum to +16. Of the 1048576 possible 20-bit cross correlations, a huge 772616 will sum to +4, +2, 0, -2, or-4. Put another way, a tad over three quarters of all of those possible 20-bit interfering signals will be strongly attenuated by your correlator. As you go to longer codes, the odds of noise interference become astronomically low.

I've now posted a quick-and-dirty autocorrelation generator to *GEnie* PSRT as my file #435 AUTOCORR.PS. As is, this will generate *all* of those unique autocorrelation codes up to 20 or so bits in length. Yes, duplicate codes are discarded and not reported. And you can easily extend out this technique to quickly and accurately find autocorrelation functions as long as 65536 bits!

Written in PostScript, of course. The trick is to put all your ones and zeros into a string. Then play around with the string. This bypasses the precision limits of any conventional digital arithmetic. Sneaky, huh?

We will be seeing much more on correlation in some future columns. Especially if we do get into more on spread spectrum communications and

1000	100010	1000101	10010101
10000111	1000010101	10010101010	10000110011
100000011111	100000000011	100100101010	1000000101001
10000001011001	1000010001001011	1000001001110101	100000010111001
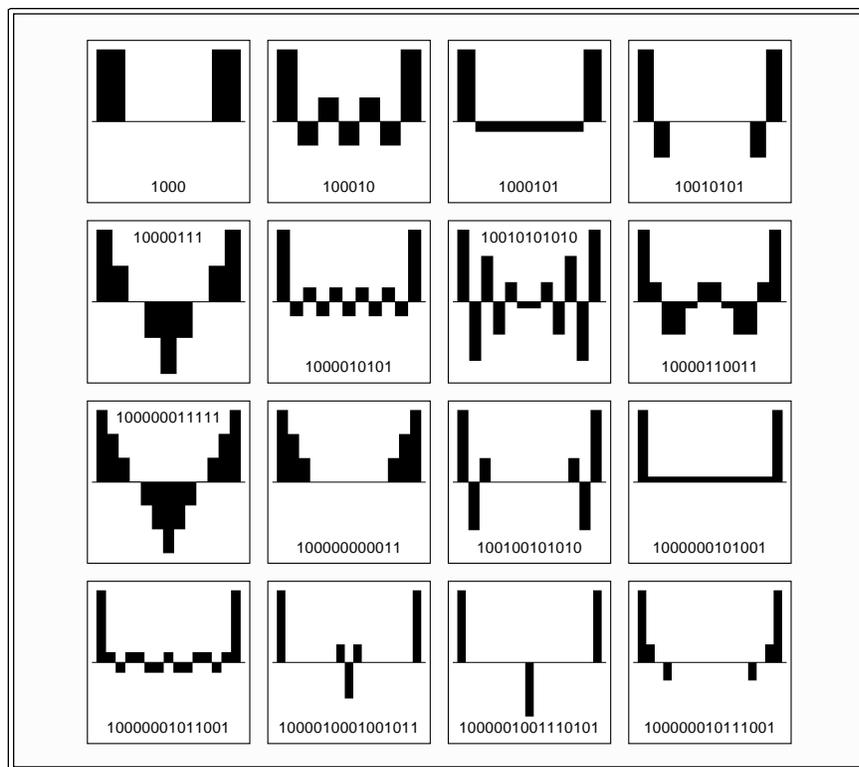
Fig. 3 – SHIFTED AUTOCORRELATION FUNCTIONS appear when you correlate a digital word against a time-shifted or bit-shifted replica of itself. These functions get important in a hurry whenever you are trying to lock onto an incoming digital data stream. These examples are from GEnie PSRT #427.

GPS navigation. I just wanted to give a bare bones intro to a tricky topic here. All of those shifted autocorrelation functions are lots of fun to play with (and a winning school paper topic) just because they are there.

Let's wrap this up by looking at two wildly different examples for electronic correlation in figure five.

Say you want to build up a low voltage, high current power supply, maybe 5 volts and 100 amps. If you try using plain old silicon diodes for your outputs, you'll get a volt or two of forward drop across your diodes. And lots of waste heat and a terrible efficiency. While the newer *Schottky* diodes help some, even these are very inefficient at higher currents.

But a properly chosen and driven power transistor could have a much lower forward drop than a diode. So, instead of using diodes, you use field effect transistors as switches set up as *synchronous rectifiers*. You turn your transistor on only when you desire conduction and turn it off otherwise. The forward drop can be much lower and the efficiencies much higher.

The synchronous rectifier is most likely your least elegant correlator example. Solar energy converters are another area where high rectification efficiencies are super important.

Shortly after World War II, pulse radar systems hit their limits. The *resolution* of a traditional pulse radar is inversely proportional to its pulse *width*; the *range* is proportional to the energy inside the *pulse area*. Ideally, you want an super powerful yet ultra narrow pulse waveform. And yew jest caint get there from here.

The trick is to conjure up some method of sending a *long* pulse that still gives you acceptable resolution. And the solution was called *chirp*. By sending a longish linearly swept FM pulse out and then by routing the received swept waveforms through a *linear delay vs frequency network* (a fancier example of a correlator), the individual bits and pieces of that swept waveform would *pile up* and generate a narrow target pulse.

The exotic *coherent* radar systems even went one step further, especially those that were side looking. The swept transmitted chirp pulses were suitably recorded, generating what were known as *target phase histories*. These phase histories were converted into viewable data by using linear delay-vs-frequency networks, optics that made a *Fourier Transformation*, holography techniques, or electronic digital correlators. All of these do a correlation in one manner or another.

Chirp may sound really complex and hairy. But bats have done it for eons. Compactly and elegantly in wetware. And the bat's "figure of merit" for their radar beats out our best and newest military radars by some ten orders of magnitude. That's 10,000,000,000:1. And not half bad for amateurs.

But, in all fairness, they did have a head start.

Printed Circuit Update

From time to time in the past, we have looked at the new *direct toner* method for making printed circuit boards. The new direct toner method promises to revolutionize hacker pc boards, doing the job in minutes for

In a SYNCHRONOUS RECTIFIER, power switches are turned on only when conduction is desired. Because of the lower forward drop of a switched transistor, the efficiencies can be much higher than using ordinary silicon diodes in low voltage, high current supplies.

In a CHIRP radar system, a frequency swept pulse is transmitted that permits both high power (for long range) and narrow time resolution (for closer target separation.) A linear delay-versus-frequency correlator converts the received target swept phase histories back into actual viewable or recordable target maps.

Fig. 4 – AS THESE TWO WILDLY DIFFERENT EXAMPLES show us, there are now an incredible number of applications for electronic correlation techniques.

pennies with zero darkroom work or other special techniques.

The two key secrets to the direct toner method are that a laser printer toner does make an outstanding etch resist; and that the great PostScript computer language makes printed circuit layouts exceptionally fast, fun and easy to do. From *any* computer, using nothing but your favorite word processor.

One early transfer film sheet was the TEC-200 film from *MeadowLake*. Sadly, many hackers swore at this new product, rather than by it. Even though many of the partial transfer problems were caused by improperly cleaned boards, not doing a preetch or preheat, by using any old copier (instead of a SX laser printer), and trying to use an iron (instead of a Kroy Kolor machine or suitable heat press of some sort).

As we saw last month, a very much improved transfer film is now offered by *Technics Inc* as their PCBF-1000. Both these products suffer a common flaw: They both expect a *differential transfer* to take place reliably in the real world. You first ask all of your toner to loosely stick to the transfer film. Later, you expect all of your toner to strongly adhere to the board, leaving zero residue on the film.

The differential transfer problem has been solved in spades by a brand new *Toner Transfer System* offered by *DynaArt Designs*. The system is basically a polyester film coated with some high tech sugar water. There are two different ways you use the film, called the *cold method* and the *hot method*. Both methods open all sorts of new hacker opportunities.

The hot method is best for hacker circuit boards. With the hot method, you will laser print a backwards but positive image by using an SX printer with a good grade of graphics refill toner. As with the previous films, you then iron the toner onto a super-clean bare printed circuit board. You now have toner that is very tightly stuck to *both* the pc board and the film.

Soak your board in warm water for a few minutes, and all the high tech sugar water dissolves, *floating away the backing sheet*. And leaving pretty near all of the toner on your circuit board nearly all of the time. Gently wash in warm water to remove any residue. Then etch as usual.

DIRECT TONER PC RESOURCES

Black Lightning
Riddle Pond Road
West Topsham, VT 05086
(800) BLACK99

DynaArt Designs
3535 Stillmeadow Lane
Lancaster, CA 93536
(805) 943-4746

The Flash
Riddle Pond Road
West Topsham, VT 05086
(800) BLACK99

Kepro
630 Axminister Drive
Fenton, MO 63026
(800) 325-3878

Lazer Products
12741 E Caley Ave #130
Englewood, CO 80155
(800) 843-5277

Meadowlake
Box 497
Northport, NY 11768
(516) 757-3385

Midnight Engineering
111 E Drake Road Ste 7041
Ft Collins, CO 80525
(303) 491-9092

Recharger
101 Granite Street Ste F
Corona, CA 91719
(714) 371-8288

Supplies Unlimited
101 Granite Street Ste F
Corona, CA 91719
(714) 371-8288

Techniks, Inc
45 J. Ringo Road
Ringoes, NJ 08551

The cold method is best for circuit board component callout overlays, dialplates, and ordinary decals. Print your normal and positive image to the film. Then spray your image using several light coats of a clear lacquer, urethane, or epoxy. Cut out all your images slightly oversized and soak them in warm water. Then transfer your images just as you would any model railroad decal. You can either remove the lacquer with alcohol to get at the bare toner, or add additional and more protecting clear sprays for extra durability.

Those cold method results do look especially impressive when you use a *Canon* color copier. Note that you can now transfer toner onto *anything*. The cost of is five sheets for $9.95.

As this month's resource sidebar, I have gathered together a few of the better known direct toner resources. Besides the three films we just looked at, *Kepro* is your leading source of hacker printed circuit supplies. More on the direct toner method is likely to appear in *The Flash* or in *Midnight Engineering* magazines. My two very favorite toner sources remain *Lazer Products* and *Black Lightning*, while others advertise in the *Recharger* and *Supplies Unlimited* magazines.

I've recently posted my shareware PostScript printed circuitry layout package over to *GEnie* PSRT as our file #401 PRNCRCT.GPS. Plus a new summary tutorial on the new hacker printed circuit techniques as file #419 NUTS3.PS. And new stuff on toner in general as #435 TONERTRX.PS.

New Tech Lit

Two reliable sources for foreign semiconductor replacements are now *MCM Electronics* and *Consolidated Electronics*. Both have free catalogs available on request.

A free video on laser printer repair training is now available from *Don Thompson*. Don is highly regarded as having *the* finest training services in this field. Besides stocking most of the hard-to-find replacement parts.

Two environmental trade journals are *Environmental Protection* and *Pollution Equipment News*. The latter has plenty of ads for interesting and unusual sensors.

For lots more info on Santa Claus Machines, check out the brand new stereolithography user's group up on *GEnie* UNIX. And a good tutorial on wavelets has appeared on page 16 of *Dr. Dobbs Journal* for April 1992.

Two free software sources for this month: *Iterated Systems* has a free demo diskette on their new *real time* fractal decompression software. And *Burr-Brown* has a new freebie *Active Filter Design* disk available.

If you are at all interested in active filters, also be sure to check out my classic *Active Filter Cookbook*. This is available by itself or as part of my *Lancaster Classics Library*. ❖

Don Lancaster's

Hardware Hacker

September, 1992

Oh, the times, the times they are a-changing. We seem to have a mix of really bad and really awesome stuff coming down lately. Let's start off with some of the sadder vibes…

Heathkit has recently discontinued production on most of their electronic kits. The end of an era for sure.

BUT – A funky little outfit called *Musty Manuals* is setting out to stock and make available all of those older Heath assembly books and instruction manuals. And lots of exciting hacker kits are newly being made available from such outfits as *PAIA*, *Elector*, *Old Colony*, and *Micro Mint*. Plus, of course, through several of our fine **Electronics Now** advertisers.

The technical paperback book field (especially the non-computer titles) is clearly not well. *SAMS* is essentially gone, triaged into the most ethereal shadow of what once was the most respected and diversified technical book publisher in the world. *TAB* has gotten itself both conglomerized and three-piece suited. And I have been getting plenty of helpline complaints over several other sources that offer dated, foreign, and inaccurate titles. Believe it or don't, your IRS is now *paying all publishers to shred books*. Especially old technical paperbacks. In sort of the same way farmers are paid not to grow crops. Through an obscure inventory ruling which has totally decimated long term back lists and older technical titles.

BUT – An incredibly exciting new opportunity called *Book-on-demand* publishing is emerging in which you can produce first quality paperback and hardback books literally on your kitchen table *when and as they are ordered*. With a "forever" backlist, no IRS inventory penalties, and no lower limit to your total number of sellable volumes needed. And including such exciting possibilities as a 90 percent author's royalty and rapid CD ROM distribution.

Much more on this on *GEnie* PSRT. For starters, download our two files DEMAND.TXT and DEMAND.PS.

Very alarmingly, some community colleges are outright eliminating their electronics departments. Or else are sharply cutting back on them. And many of those electronic service and repair trade journals have now vanished without a trace.

BUT – We now have got the richest and most incredible variety of cheap new chips to play with. Anywhere. Ever. We have major breakthroughs in hacker direct toner printed circuits. We have got a brand new **Electronics Now** format with new features and fresh ideas that continues the oldest ongoing electronics publishing house. And we are something like a scant eight years away from hardware that can surpass the human brain in logic and analysis capabilities.

Right now is certainly the greatest time *ever* to be getting into hardware hacking in a *very* big way.

Electronic halftones

I've recently been playing around with the new *LaserWriter G* and am *very* impressed with its new ability to print medium- to high-quality photo halftones. So, I thought we might review what is involved in the laser printing of photos in general. And see just why Apple's neat *PhotoGrade* process seems to elegantly beat out the brute force methods.

And how we can do even better.

Many of those previous generation laser printers were 300 DPI devices, capable of placing or not placing 300 whole dots per inch uniformly along any one selected laser scan line. This translates up to 90,000 dots per square inch, or a tad over 8 million dots on a standard page. If a dot is only black or white, it can usually be represented on the *page bitmap* or else in the *frame device* as a single bit. Thus, around a megabyte worth of memory must be reserved for your full page bitmap at 300 DPI resolution.

The obvious big dilemma in raising your laser printer resolution is this: As you go from 300 DPI to 1200 DPI, you could end up requiring *sixteen* times the memory! And your page makeup times could end up *sixteen times* as long! Yet "more" resolution is clearly perceived to be a big user need.

Or is it?

Actually, laser printing resolution is pretty much as highly overrated as *Peterbilt* trucks or teenage sex. But that's another story for another time. I strongly feel that higher resolution is not worth losing genuine Adobe Level II PostScript, duplex printing options, low 0.2 cents per-page printing costs, mainstream technology, useful third party supply sources, local hard disk support, or any sleep over.

At least for most people most of the time. And a poorly scanned photo (or
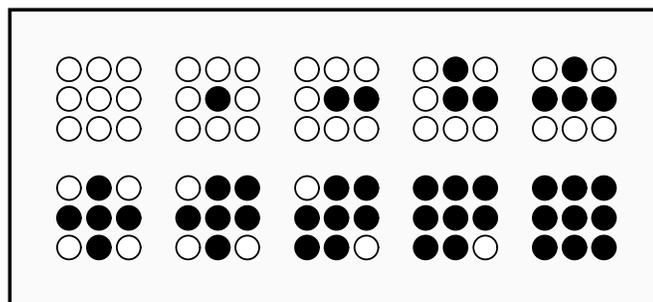
Fig. 1 – A LASER PRINTER can fake a halftone by grouping dots into a larger "cell". In this example, a 3 x 3 pixel array forms a cell that can have ten gray levels, including black and white. On a 300 DPI printer, this would form a "100 line, 0 degree" halftone screen.

one that is not properly histogram equalized) could end up looking even worse on the premium machines.

One zero cost way to increase your printer's resolution when you'd like "camera ready" art for conventional printing: Just work oversize and then photoreduce. Most of my Hardware Hacker figures are run at *133* percent normal size, thus giving an effective resolution of a scant *400 DPI* Yet I feel they look as good as most of the other technical figures.

An easy way of making a *300 DPI* printer look better is to do a plain old smoothing. Which was pioneered by Hewlett Packard as their Resolution Enhancement Technology .

Apple (and many also-rans) have copied this idea. On the LaserWriter G, Apple calls it FinePrint .

The smoothing is done by a custom integrated circuit that intercepts and stores a few of the scan lines on their final way out to the laser scanner. By analyzing a matrix formed from the nearby dots on earlier and later lines, certain dot positions are delayed by one-half a dot, following a smoothing algorithm. Which results in a really big improvement in most typography and some graphics, escpecially for any slanty lines.

Despite all of the hype, the circuitry involved is simple and cheap. And it can end up totally independent of the imaging model or language in use.

But plain old smoothing can't help halftone photos any. And may even hurt. Let's look further at…

The halftone process

There is only one method to print something that is truly gray on the page. And that is to use gray ink. And each different shade of true gray will need a different gray ink and another pass through the printing press. Since this is clearly ungood, printers have long used a halftone process instead.

The halftone process consists of printing lots of different sized black dots very near to each other. The dots are carefully spaced to be below the eye's angular resolution. Instead of seeing the individual dots, your eye averages out the black dots and the white background and perceives an average gray level. The higher your ratio of white to black, the lighter the gray, and vice versa.

Let's try it. Now, this might look like it is gray…

But get out your magnifying glass, and you'll see all the little black dots used for this *106* line halftone screen . The dots are all black.

To print any photograph, a special screen is used on the litho camera to convert grey values into collections of black dots of varying size.

Traditional printers will spec their screen size as the number of halftone spots per inch. Some popular final screen frequencies include *85* spots per inch for tabloid news and the *120* spots per inch for most magazines of *Electronics Now* quality.

Even higher spot densities get used on premium magazines. But these do take special inks, coated papers, and extreme attention to detail.

300 SPI, 0 degrees — 2 grays
212 SPI, 45 degrees — 3 grays
150 SPI, 0 degrees — 5 grays
134 SPI, 27 degrees — 6 grays
106 SPI, 45 degrees — 9 grays
100 SPI, 0 degrees — 10 grays
95 SPI, 18 degrees — 11 grays
83 SPI, 33 degrees — 14 grays
75 SPI, 0 degrees — 17 grays
73 SPI, 14 degrees — 18 grays
71 SPI, 45 degrees — 19 grays
67 SPI, 27 degrees — 21 grays
60 SPI, 0 degrees — 26 grays
60 SPI, 37 degrees — 26 grays
59 SPI, 15 degrees — 27 grays
56 SPI, 23 degrees — 30 grays
53 SPI, 45 degrees — 33 grays
51 SPI, 31 degrees — 35 grays
50 SPI, 0 degrees — 37 grays
49 SPI, 10 degrees — 39 grays

Fig. 2 – THE AVAILABLE SPOT PATTERNS for a typical 300 DPI PostScript printer. Note that these are the ONLY dense patterns available. You'll get one of these regardless of what you ask for. Also note the perfect tiling.

Note that even the very highest spot densities used are nowhere near *300* spots per inch!

A second halftone parameter gets called the screen angle . It turns out the human eye is very good at picking out horizontal and vertical lines, but rather poor on resolving diagonals. Since the halftone process can introduce visual artifacts , it is often best to set your black and white screens on a *45* degree angle. In color printing, the halftone screen angles can become even more critical if they are to eliminate most objectionable Moire patterns.

There are several methods to fake halftone screens on the laser printers. One is to group all the possible laser dot positions into larger spots that I'll call a cell . Figure one shows you how a *300 DPI* printer can use nine dots to make cells of *100* spots per inch. This particular cell has a screen angle of zero. As you can see, there are ten possible gray levels here, including black and white.

We can immediately see that we could use thirty-six dots to form *50* spot per inch cells. And these cells would give us thirty-seven possible grays. Clearly, we do have a tradeoff between the number of cells per inch and the number of available grays. Use too few cells per inch, and you'll get the "Sunday Funnies" effect with very grainy dots. Use too few grays, and you will solarize with obvious (and often objectionably bad) steps between each possible gray level.

The gray level resolution of your eye depends on context and contrast, but something slightly over *256* gray levels is often possible. But, because of the stupendous costs of exceeding *256* grays, most experts agree that eight bits of gray scale resolution is "enough" for even the most premium images. Television sometimes might get by on as few as six bits, good for a mere *64* gray levels.

The obvious next question is "How good can our halftones image at an unenhanced resolution of *300 DPI*?" Ignoring the obvious answer of "Not good enough", we'll then go on to ask "What can we do about it?"

PostScript to the rescue

I've discovered that the PostScript general purpose computer language has some really great approaches to electronic halftones. These do involve their setscreen and image operators, among many others. PostScript uses some imaging tiles that determine the screen angles and frequencies. Since these screen tiles must all abut each other perfectly and still must follow integer (whole numbers only) math, there are very definite limits to which *300 DPI* tiles are possible.

If you ask for some halftone cell angle or frequency that is simply not physically possible, PostScript will substitute the nearest handy one.

Figure two shows you the available denser halftone cells as used on most
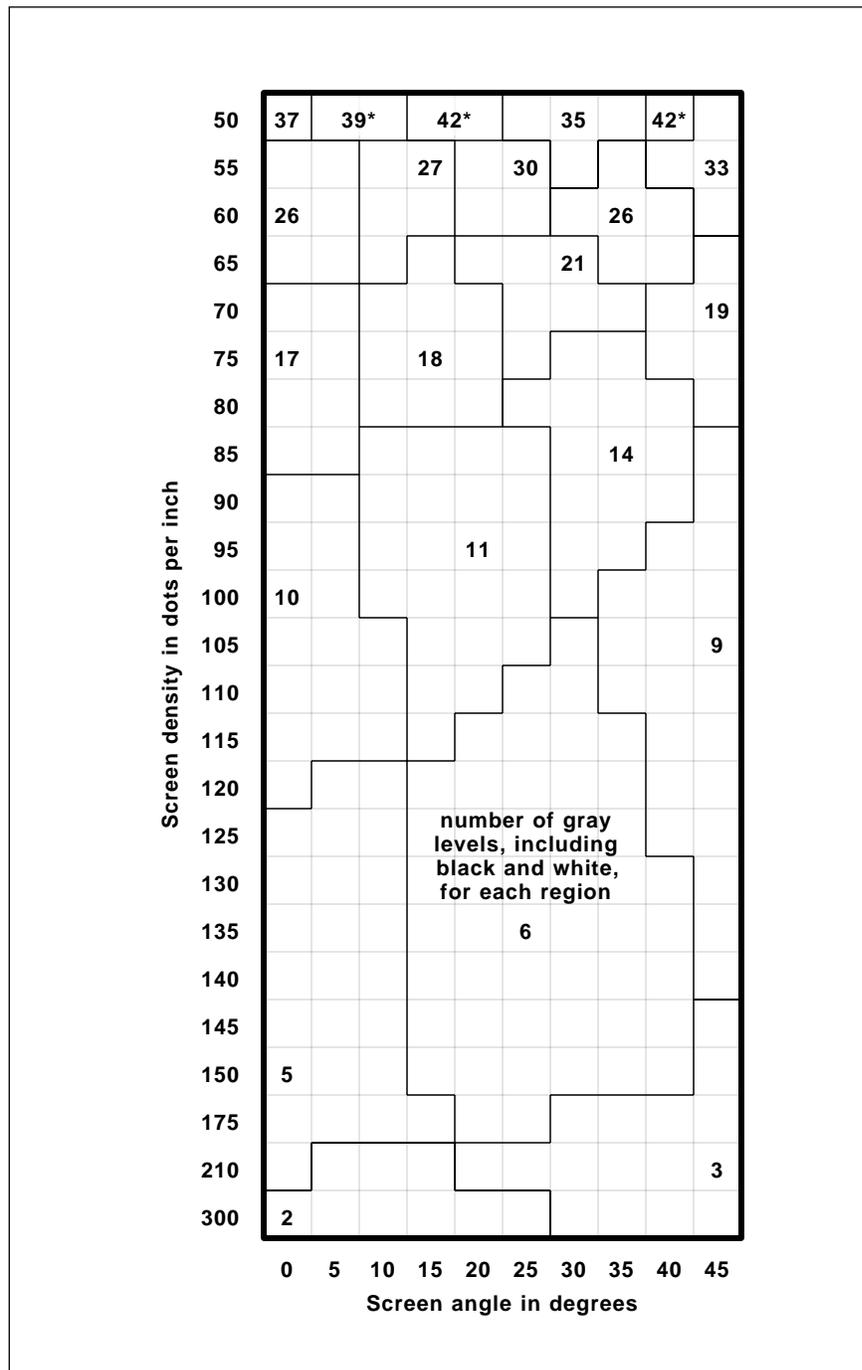
Fig. 3 – THE TOP SECRET GRAY MAP for a 300 DPI PostScript printer. Most users and most application packages insist on using the seventeenth most putrid of the available grays. The "best" graphics gray is 106 DPI at 45 degrees.

popular *300 DPI* PostScript printers. Figure three shows you the secret gray map for all of the "hidden" PostScript grays you can use.

Typical PostScript users and most applications packages blindly insist on choosing the seventeenth most putrid PostScript gray available. While this is often incorrectly labeled a *60 DPI* screen, its effective resolution is only *53* dots per inch. There are *33* grays with this default screen.

Which sort of explains the "Sunday Funnies" effect of most poorly done PostScript screens. And one of the biggest reasons why people feel they need "more" resolution. When in fact, their grays could all get instantly and dramatically improved by using a few dozen keystrokes!

Ferinstance, the "best" PostScript *300 DPI* halftone screen for typical graphics is a *106 DPI*, *45* degree one which gives you absolutely beautiful grays. Sadly, you'll only get ten of these grays, but the lightest ones are very good for graphics.

Two other quite useful *300 DPI* secret PostScript grays of interest are the *85* line and *35* degree "reprogray" useful for oversize camera ready art, and the *135* line, *25* degree "india ink wash" gray. The latter gives you only six gray levels and requires a careful selection of toner and paper. But the results are stunning.

For photo halftones, you might like to try the *73* spot and *14* degree screen having eighteen grays. Or else the *71* spot, *45* degree screen with nineteen grays. Using an extreme amount of care, these can become just barely useful in certain applications.

No, none of these screens can give you any high quality halftone photos. But the *71* line screen can give you a recognizable "auto shopper" quality photograph. Especially if the scanned image has been properly histogram equalized.

One way to do a "best" PostScript gray is to enter these keystrokes as PostScript commands…

106 45 {dup mul exch dup mul
add 1.0 exch sub} setscreen

The very first number is your cell frequency; the second is your angle. The details of where and how you enter these code lines depend on your PostScript programming style or the applications package.

Call me if you need any further help on this.

We may see quite a bit more on image enhancement next month.

Three key points: The halftone dots used in everyday printing are much coarser than *300 DPI*. Some excellent graphic PostScript grays are available at *300 DPI* that only need a few dozen simple keystrokes for their activation. And our halftone photo quality, when given properly image processed input,

doesn't miss by that much.

So we can potentially add only a little to *300 DPI* and gain enormously on halftone photo quality. Both QMS and IBM/Lexmark picked the brute force method. As figure four shows us, they switched to a *600 DPI* double resolution and then swallowed the *4:1* speed and memory penalties. At *100* cells per inch, you now have *37* gray levels. Or *50* gray levels at an *85* cells per inch density.

Which could makes the difference between "lousy" and "not half bad" photo halftones. Especially given a proper digital image processing.

Apple has chosen the more elegant PhotoGrade method of figure five. They remained at *300 DPI* but added three extra bitmap memory planes for a total of four. Then they modulated their laser dot size to one of sixteen values. You now could have sixteen times as many potential gray levels as you did at *300 DPI* with only a single memory plane. At *106 DPI* you now have a much better *128* gray levels available. Which is equal to a brute force resolution of *1200 DPI*.

There is only a negligible speed penalty, since all four memory planes are written in parallel using custom *LSI* chips. And while you retain the same *4X* memory penalty as a brute force *600 x 600*, you'll get four times the effective resolution!

The results? Good to better photo halftones out of any plain old *300 DPI* laser printer engine. Especially with premium toner and properly scanned image processing.

The PhotoGrade is also upgradable on older *NT* and *NTX* printers with a simple plug-in board swap.

Can we do better?

I think we can. At least in theory. For any *100* spot per inch tile at plain old *300 DPI*, we are using nine bits to call out only *10* different spot values. Since nine bits could represent *512* different state values, the memory use efficiency is a tad under two percent.

Wowie gee.

The PhotoGrade does ridiculously worse. Here we are asking thirty-six bits to call out a mere *144* different gray levels. Since thirty-six bits can yield us up to *68,719,476,736* different states, our memory use efficiency is essentially zero!

old 300 DPI
pixel size

new 600 DPI
pixel size

(100 DPI, 0 degree halftone cell shown)
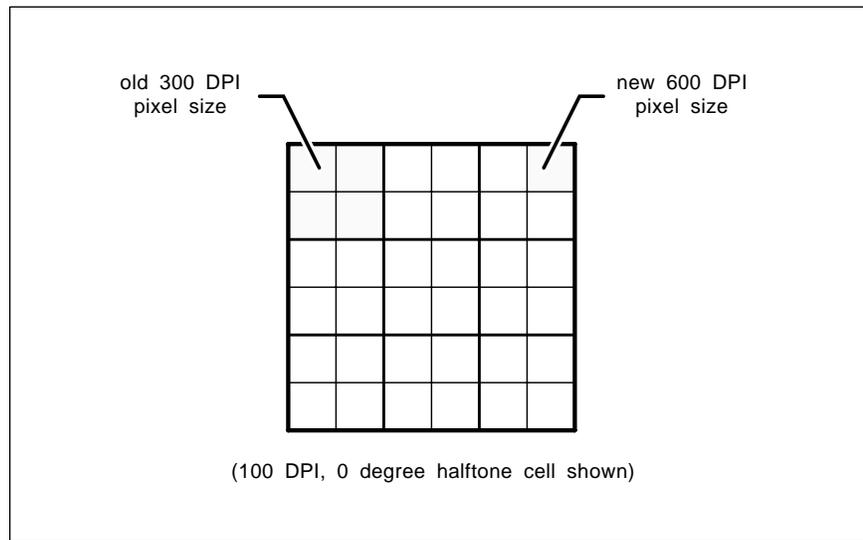
Fig. 4 – BOTH QMS AND IBM/LEXMARK chose the "brute force" 600 DPI method to improve their PostScript photo halftones. The original 100 DPI spots allowed 10 gray levels; the new ones allow 37. There is a 4X speed and 4X memory penalty for the modest (but certainly welcome) improvement.

Thus, virtually all of that Apple PhotoGrade memory bitmap is totally wasted!

Instead, let's go back to, say, *100* spots per inch at a plain old *300 DPI* Once in the center of every desired halftone spot, put out a single laser dot having up to *512* possible size values. Presto. A mind-blowing total of *512* grays at *100 DPI* Or a "perfect" *256* grays up at the usual *106 DPI!*

What would happen is this: The laser scanner would run in one of two selectable modes. In the normal PostScript mode, the dots go down at the expected resolution. In the photo halftone mode, fewer and much larger dots go down at the expected halftone screen resolution.

Even if an entire bitmap was needed to keep track of modes, this would still be up to twice as memory efficient as PhotoGrade, while still delivering up to four times the actual number of resolvable photo grays.

But a simple old mode list could possibly be used instead. Yielding a zero memory penalty for top quality photo halftones.

This for photo halftone dots only; you would still be able to do special screens and weird spot functions the old way. Patterns, too.

Note also that your laser printer would now be doing variable sized dots in exactly the same manner that "real" printing halftones usually go down on the page.

For us to fully utilize what seems theoretically designable, you would need some special automatic mode sensing for the halftone areas. And a diamond-shaped laser beam whose diameter can be controlled over a *25* decibel or *16:1* range. Down from a maximum slightly under three times larger than now gets used. None of these needs seems a really big deal.

Thus, it should be theoretically possible to build a *300 DPI* PostScript laser printer with outstanding photo halftones. A *1697 DPI* equivalent. At zero speed or memory penalties.

Hmmmm…

I have posted lots of halftone and secret gray study examples to GEnie *PSRT*, especially in my files *129, 141, 144, 179, 180, 231,* and *239*. I've also uploaded some high quality images that you can play with, either inside or outside PostScript. In particular, check

out *LENA.PS, MANDRILL.PS,* and my enhanced *LENAHIST.PS.*

Marketing your products

I was pleasantly surprised that the leading invention marketing firms are now publishing their track records. Up front in their initial mailings. One of the oldest and largest discloses: Of the ideas submitted and contracted, the odds of getting a royalty license are *100:1* against, and the odds of any positive cash flow that exceed costs are *600:1* against.

These figures sound about right to me. Sometimes I've done almost that good on my own. And sometimes not. Selling an idea is a real rough row to hoe. One that could become a near impossibility if you are not a fully trained and well experienced insider attuned to the trade journals, political realities, seminars, economics, and tech literature of the target field.

An invention marketing firm is just a hired gun, similar to an ad agency or a resume typing service. You pay them for their time and effort. For such services as patent searches, for listings in product newsletters, and promotion at invention fairs.

Cash up font.

Naturally, asking anyone at any invention marketing outfit whether your idea has any value is about as bright as asking any auto salesman

whether you need a new car. Or an ad agency whether you need an ad. Or a mugger whether you need mugged. Come on now. What did you expect them to say?

As we've seen a number of times in the past, the core problem lies in the absurd mythology surrounding today's patent system. Very simply, patents have little to nothing at all to do with the selling or marketing of an idea. For most individuals and most small scale technical startups, any involvement whatsoever with the patent system is virtually certain to end up as a net loss of time, energy, money, and sanity .

Just about all hackers will tend to grossly overvalue a new idea. At one time way back in the golden age of inventing, ideas were occasionally worth as much as one dime a dozen. Today, they are worth less than ten cents a bale in ten bale lots. Any ideas gain value only when you can clearly demonstrate your end users actually getting off on them. And then only when those ideas are already in some saleable, competitive, promotable, and distributable form.

The key secret to selling an idea is very simple: They must come to you. And never vice versa. For our special resource sidebar this month, I have tried to gather together a few useful alternatives that can help you profit from your ideas.

PRODUCT MARKETING RESOURCES

DesignTech International
7401 Fullerton Road
Springfield, VA 22153
(703) 866-2000

Encyclopedia of Associations
835 Penobscot Building
Detroit, MI 48226
(313) 961-2242

GEnie
401 North Washington Street
Rockville, MD 20850
(800) 638-9636

Inventor-Entrepreneur Network
1683 Plymouth Road
Ann Arbor, MI 48105
(313) 663-8000

Micro-Mint
4 Park Street, Suite 20
Vernon, CT 06066
(203) 875-2751

Midnight Engineering
111 E Drake Road Suite 7041
Ft Collins, CO 80525
(303) 491-9092

PAIA Electronics
3200 Teakwood Lane
Edmond, OK 73013
(405) 340-6300

Redmond Cable
17371-A1 NE 67th Court
Redmond, WA 98052
(206) 882-2009

Synergetics Consultants Network
Box 809
Thatcher, AZ 85552
(602) 428-4073

Whole Earth Review
27 Gate Five Road
Sausalito, CA 94965
(415) 332-1716

Two essential magazines are that Midnight Engineering and the Whole Earth Review . There are bunches of independent and non-profit inventor's organizations out there. One I can heartily recommend is Ed Zimmer's Inventor-Entrepreneur Network . For other regional sources, check out the Encyclopedia of Associations you will find at your local library.

No, I just do not know of anyone anywhere that is dumb enough to buy raw, unproven, or undeveloped ideas. But I do know of several someones who sometimes may be interested in looking at tightly targeted products if these products are already in their pre-production prototype stage and are currently under active end user beta testing .

For instance, Mark Gottleib of his Design Tech International is looking for innovative approaches to low end consumer electronics, especially for those items that can be blister packed and need no smarts to use.

Dennis Carper of Redmond Cable is seeking out tested and already proven interconnect and adaptor products that can clearly solve some obvious and well defined problems.

John Simonton of PAIA sometimes looks for items with kit possibilities, especially if they are related to *MIDI* or electronic music.

And Steve Ciarcia of his Micro Mint is occasionally interested in any embedded processor aps. If they are genuinely unique.

Once again, please don't hassle any of these folks unless you are well into a real world beta test. And then make certain it applies to them.

Besides my own *PSRT* RoundTable on GEnie , you also just might want to check out their *HOSB*, short for Home Office and Small Business .

I've also more or less put together my ongoing, loosely knit Synergetics Consultants Network that centers on our voice helpline. There's no charge for referrals to a consultant in our data base. If you are a consultant and want to participate, there is a five percent referral fee, due when and as the work is actually completed and collected for. And out the door.

Give me a call at *(602) 428-4073* if you need any more info. Best calling times are *8-5* weekdays, in Mountain Standard Time .

New tech lit

From Texas Instruments , seven pounds of revised linear data books. Volume *I* on op amps; *II* on *A/D*, *DSP*, and video; and volume *III* on voltage regulators and really oddball stuff.

A pair of very readable new books: The Triumphs and Trials of an Organ Builder , by Jerome Markowitz, *CEO* of Allen Organ , and published by the Vox Humana Press . Among the other things, it reveals how trivially easy it is to have any technically solid and perfectly valid patent busted in court. Just because some epsilon minus does not happen to like you.

Plus Accidental Empires by the pseudonym Robert X. Cringley , and newly published by Addison Weseley . Subtitled How the boys of Silicon Valley make all their millions, battle foreign competition, and still can't get a date . This book has a double handful of quite funny one-liners in it. But otherwise reads like something that Cringley would write.

I've found very few trade journals available on electronic servicing. One useful new one, though, is MSM, the Magazine of Service Management . A big emphasis is on computer service, especially handy sources for printer and disk drive replacement parts and assemblies.

A great collection of navigation books, *GPS* and otherwise is offered by the Navtech Information Service . And a new Spread Spectrum Scene labor-of-love newsletter has recently started publication.

Two additional firms apparently still offer top octave generators and other classic electronic organ chips. The first is Fistell Microelectronics , and the other is Keyboard Systems. The latter also builds workaround replacement modules for chips that are truly unavailable.

Turning to some of my very own products, yet another obvious and major product selling resource is my recently improved Incredible Secret Money Machine II . The autographed copies are available per my nearby Synergetics ad.

As usual, we've gathered many of the resources mentioned together into the Names & Numbers appendix or into the Product Marketing Resources sidebar. Do be sure to check these out before you use our no-charge tech helpline or calling for a free hacker secrets brochure. ❖

One-of-sixteen dot size output to laser scanner

4-bit D/A converter

"8" bitmap   "4" bitmap   "2" bitmap   "1" bitmap

(100 DPI, 0 degree halftone cells shown)
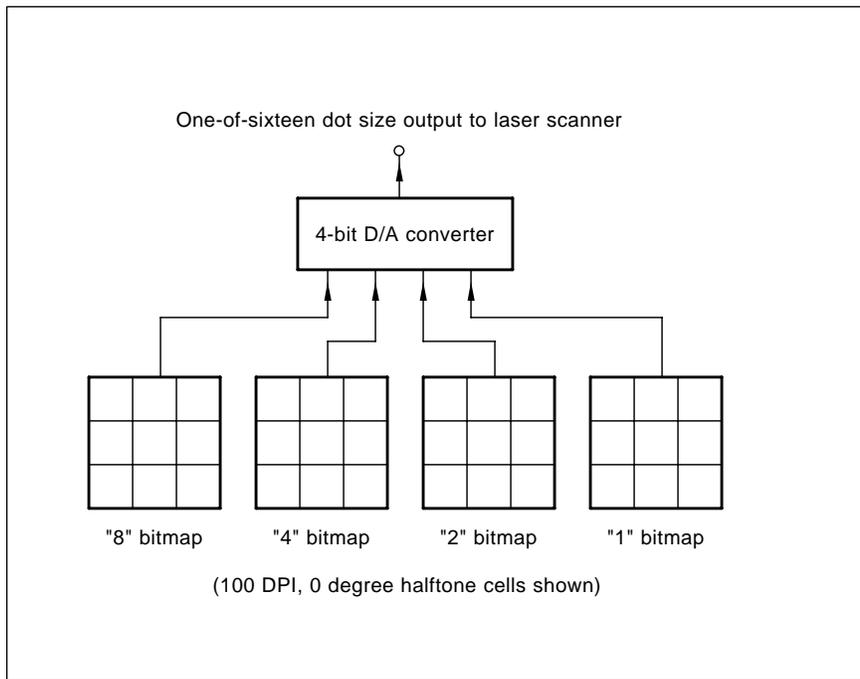
Fig. 5 – THE APPLE LASERWRITER G remains at 300 DPI, but uses four bitmap memory planes that allow one of sixteen pixel dot sizes. This permits 144 gray levels at 100 DPI for good- to better-grade photo halftones. Or 128 gray levels at the more popular 106 DPI and 45 degree screen.

Don Lancaster's
Hardware Hacker

October, 1992

Stop the presses. *Murata* has just announced a *Gyrostar* piezo gyroscope. Which, if it is as great as it looks, could easily become *the* hacker component of the decade. All I've got on this so far is that brief note in the June 8th *Design News* and a promise for more tech info. Needless to say, the hacker potential of a $5 nav gyro would be truly revolutionary.

Be sure to stay tuned on this one.

Things are also starting to happen fast and furious on that direct toner printed circuit board front. Since my last report, the new and water soluble decal based *Toner Transfer System* offered by *DynaArt* has been further improved. The new *Printed Circuit Board Transfer Film* from *Techniks* looks even more promising.

What Techniks did was take their old differential transfer system and add a new and blue polymeric release coating. This poly release coating can dramatically improve the transfer and actually becomes an important part of your resist pattern.

Faster than the speed of light?

Every week or so I get at least one letter or a helpline call from someone who feels they have clearly broken some physical laws. Maybe they have proof that the speed of light is not a constant. Or that those three laws of thermodynamics just do not apply to them. Or that perpetual motion can be possible using magnetic repulsion. Or they have tapped the zero point scalar energy from the fabric of space. Or that their latest pet theory proves the cold fusion process.

Usually, they'll also complain that they've sent their theory everywhere and have gotten zero replies. Or that they are getting ignored because they are an outsider.

Very often, their inquiries will be self-defeating. How? By including totally irrelevant religious or political contexts. Or by being super secretive. Or written and submitted in such a way that they scream "Hey, kick me, for I'm not even computer literate."

If it likes water, looks like a duck, and quacks like a duck…

But consider who is receiving these letters. Based on past experience, the editors or the publishers *know* that the probability is 0.99+ that the lab work (if any) is just plain wrong. Or, more typically, *not even wrong*. And 0.99+ that the sendee is clearly a few chips shy of a full board. Why *should* they believe you?

The sad thing is that needle in the haystack. I'm going to be generous and claim that one letter in 500 in fact *does* have the germ of a new theory or a developable product or a fresh look at a solvable problem. And, yes, newer ideas often get ignored or vehemently attacked.

What can you really do if you have genuinely beaten those overwhelming odds and your controversial idea is in fact both new and for real?

There are two possible routes you could take to get your ideas accepted. The first or *real science* method is to *thoroughly try and prove that you are wrong*. Be sure to use lots of careful research, especially through *Dialog* and those *UMI* reprints. Be certain to subscribe to *all* of the relevant insider trade journals and go out of your way to study the scholarly publications in the field. Learn all the lingo. Attend conferences and trade shows. Find a patient and knowledgeable industry insider that is willing to look at your idea and honestly comment on it.

Make absolutely certain that you have a simple experiment that can be independently duplicated and verified by disinterested outsiders.

Hire some competent engineering or physical science consultants to study and add credibility to all your claims. Do take enough college and university level courses to make sure you do thoroughly understand at least the fundamentals of the field. Along with the needed math to back it up.

And finally, you present the ideas clearly identified as a possible new theory in some professional context totally free of religious, political, or any conspiracy mumbo jumbo.

The second route is to publish via a *pseudoscience* press. There are quite a few of the underground or alternate life publications that welcome material of this type. Every now and then, that *Whole Earth Review* gives you a list and rundown of all the magazines of this genre. Let me know if you want to see a resource sidebar on these.

One leading bookstore that does specialize in selling and distributing pseudoscience topics is *High Energy Enterprises*. Many of their offerings are utterly fascinating. These folks also do sponsor several yearly forums

(A) Relay converted to latch.

(B) Inverter pair used as latch.

(C) Alternate action pushbutton.
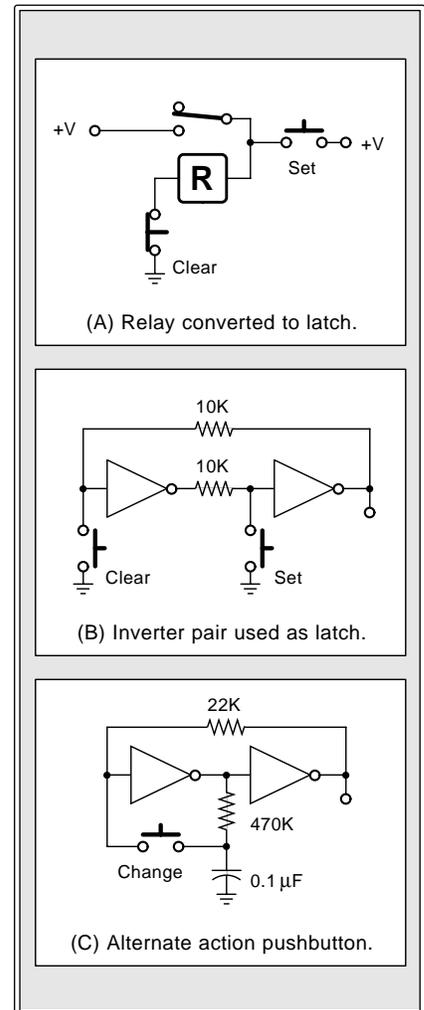
Fig. 1 – SOME SIMPLE LATCHES and alternate action circuits.

where the controversial pseudoscience topics are strongly encouraged.

Several very important tips when publishing your own pseudoscience tracts: Be sure to use cut-and-paste Xerox-of-an-Xerox and lots of poorly printed sloppy layouts. Smeared ink on cheap paper is a must. Be sure to freely quote obscure rural newspapers as your prime data sources. Do be certain to include illegible artwork. Extensively refer to unheard-of and unavailable journals. Use plenty of irrelevant inference and innuendo.

Be sure to use only *20-200 year* old references, especially in any rapidly changing field. Misquote and drop some big names, even if totally out of context and they never heard of you. "Billions and billions of Carl Sagan's ago..." Never offer any succinct and easily verified experiment.

Always use ten words where one will do. Make all of your paragraphs unbearably wide and long. Then run them all together in haphazard order. Never come right out and state your key points. Work Tesla in somehow. Be sure to include plenty of obscure religious and/or political references. Show how your theory is now being suppressed by a federal conspiracy headed by the Trilateral Commission

and secretly funded through both the *WCTU* and the *SPCA.*

Ignore all the personal computers entirely. They are only a passing fad that never will catch on. Finally and above all: Do not ever, under any circumstances, use any new desktop publishing tools and techniques.

Alternate Action Pushbuttons

I got a helpline call the other day asking for a circuit to convert any old ordinary relay into an alternate action on-off device. Well, as the caller has found out on his own, that gets a little trickier than it sounds.

Figure *1-A* does show you how to convert a regular relay into a latching relay. Press normally open button *A* and your relay pulls in. The pull in closes a relay contact that holds your relay engaged. To reset your relay, press normally closed button *B*. The relay drops out, opening its latching contact. This is a simple example of a latch , or a set-reset flip flop.

In *1-B* we've used a pair of digital logic inverters instead. An inverter outputs a one for any zero input and vice versa. Assume the left inverter happens to be outputting a one. The right inverter sees this one as an input and outputs a zero. The zero in turn

reaches around and holds the left inverter in its present state. We are thus latched and stable. Press button *A* to set your latch. Press button *B* to clear your latch.

It does turn out that any alternate action circuit has to consist of two distinct storage elements. One is for "Where am I?" and one is for "Where was I?" If you fail to provide for two storage devices, you are certain to get into major reliability, oscillation, or preferred state hassles.

In most integrated circuits, the two needed storage elements are done with a pair of separate latches. One gets called the master flip flop. The other is the slave flip flop. Often these are combined into a single more complex logic block, forming a type-D clocked flip flop or some similar device.

Check carefully, and you will even find your button on a retractable ball point pen to consist of two distinct storage devices.

The simplest and the most elegant alternate action pushbutton I know of appears in figure *1-C.* The "Where am I?" storage consists of that pair of back-to-back inverters. Your "Where was I?" storage is the capacitor.

Here's how it works: Some brief time after that latch changes, your capacitor will charge up to hold the "Where was I?" one or zero. Pressing the button forces the "Where was I?" value back onto the input of the first inverter, and the latch quickly flips.

This happens because the charge on any capacitor cannot immediately be changed. Thus, at the instant your switch is closed, the capacitor acts as a very low impedance which "force feeds" its value to the inverter input. As soon as the inverters flip, positive feedback holds your new value.

Releasing your button will let the "Where am I?" pair of inverters work normally. A short interval later, the capacitor will charge up (or down) to its new "Where was I?" value, and the cycle can be repeated.

This circuit can also be used as a relay driver. It's the fastest and best way I know of to make a mechanical relay reliably alternate its states.

While any old *CMOS* gates could be used, my favorite here would be a *74HC13* hex Schmidt Trigger.

Much more tech info on counters, latches, and state alternation appears

The **VALUE** at each **PEL** or picture element determines the brightness for that pel; the **LOCATION** of that pel in the array sets the pel position in your actual image.
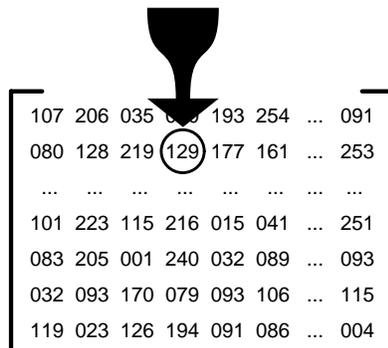
107	206	035		193	254	...	091
080	128	219	(129)	177	161	...	253
...	...	...	...	...	...	...	...
101	223	115	216	015	041	...	251
083	205	001	240	032	089	...	093
032	093	170	079	093	106	...	115
119	023	126	194	091	086	...	004

Fig. 2 – A DIGITAL IMAGE is nothing but an array of numbers. Digital image processing takes those numbers and replaces them with other numbers, following a rule or set of rules. While there is a stunning variety of uses for digital image processing tricks and techniques, two of the most important involve gamma correction and histogram equalization.

in my CMOS Cookbook .

Digital Image Processing

I never cease to be amazed at how stunningly versatile that PostScript general purpose language is. I have recently used PostScript to create a group of rapid, easy, and fun digital imaging processing tools. The tools and a few test images to go with them have been posted to my GEnie *PSRT* RoundTable as *IMAGEKIT.PS*

What I guess I'd like to do here is give you a brief intro to digital image processing. We'll limit ourselves to high quality gray-scale images.

We will also try to zero in on doing both a gamma correction and a histogram equalization . These are both highly important and little understood crucial uses for serious digital image processing. Fail to understand either one and your images will all end up disasters waiting to happen.

We'll first note that good old silver halide "slopping-in-the-slush" photo work is both incredibly versatile and highly forgiving. Besides having an enormous dynamic range.

Instead, electronic digital displays, printers, and any photosetters demand data which is always "right on". If anything misses at all, you will get lousy to useless results. Which is why digital image processing has become so important. And so hackable.

Hmmm. To do some digital image processing, you have to start with a digital image. You can borrow one of mine off of GEnie *PSRT*, or grab one from a scanner, off a satellite, a fax machine, or some live video capture board. Such a digital image is made up of picture elements or pels . Note that a pel may or may not be the same size as the final pixel on your output device. A pel is defined as the minimum resolvable data value   found in your numbers within the digital image.

In a gray scale image, a pel gets defined by three parameters. The pel luminance value will tell you how bright this tiny portion of your scene will be. Its X position value will tell you how far over in the picture this pel sits, while its Y position tells you how far up and down .

Ferinstance, in the *LENA.PS* file *#463* on up *PSRT*, we use *256* possible grays (ranging from PostScript's *0* = black smoothly up on through a *1* =

white). These pels are arranged as an image *256* bytes wide by *192* bytes high. This size was picked to be big enough to be useful and interesting, yet small enough, short enough and fast enough to have lots of fun with. PostScript, of course, can handle any image size and resolution you want.

The first byte in your data file contains the 8-bit luminance value for the upper lefthand pel. The second byte for the next pel to the right, and so on. After *256* horizontal pels, the data starts over again at the left pel of the next line down. This repeats for a total of *192* lines or *49152* bytes.

Or *48K* for short.

As figure two shows us, digital image processing simply consists of taking this large array of digital bytes and then creating a second array of new digital bytes. The bytes in your second array are related to the bytes in the first array by some rule or set of rules. And your processed new image

should now somehow be "better" for whatever you are trying to do.

For instance, we might just take each individual data value and make it larger. Which would brighten your display and give you lighter values. Make each data value smaller, and you will instead darken your display, favoring darker values.

Should there be any defect in the picture, you can "retouch" by looking at adjacent pel values and working out some type of average. And carried to extremes, this style of digital image processing can remove any telephone poles from pictures, rearrange trees, and literally leap tall buildings with a single bound.

A digital image processing trick known as an anti-aliasing lets you remove the jaggies from black and white lines. For anti-aliasing, grey values should get substituted equal to the expected average value at each pel. From nearly any reasonable viewing

Ⓐ Typical Gamma curve of a CRT electron beam display or a "white write" laser printer will wash out many of the lighter whites.

Ⓑ Properly gamma corrected display or printer treats all gray levels equally. Some available gray levels may be lost in the process.

Ⓒ Typical Gamma curve of a "black write" laser printer (such as a Canon SX) will muddy the darker grays.
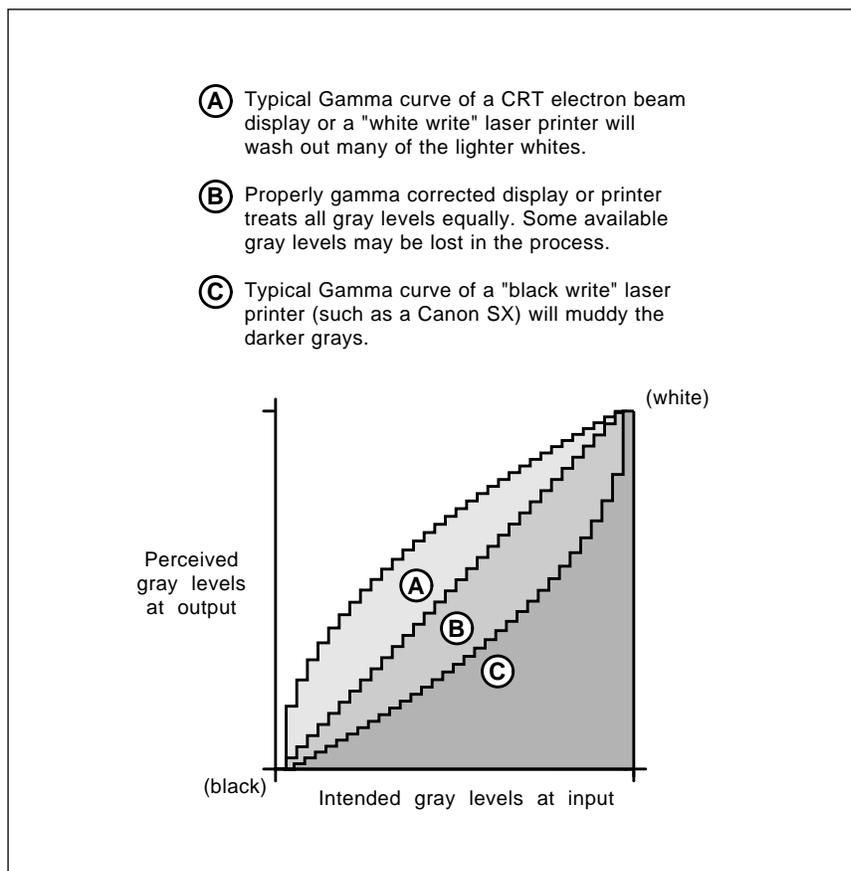
Fig. 3 – THE GAMMA CURVE for any display or printer relates how the brightness levels are viewer perceived compared to how they are input. A non-linear gamma either "muddies the lows" or "washes out the highs". Gamma correction attempts to make each gray equally significant to the end viewer.

distance, your jaggies will magically disappear. Poof.

Calculating new pel values based upon values of neighbor pels opens up all sorts of powerful digital image processing opportunities.

Ferinstance, if you average or low pass filter against nearby pels, you can soften or soft focus your image. If you emphasize any differences, you can crispen or sharpen your final image. Carried to extremes, a crispening or sharpening becomes edge detection , where only outlines remain. A magic algorithm called a Laplacian is often used for high quality edge detection.

What if your original picture is out of focus or blurry? Well, you can go to a rather fancy Fourier or wavelet transform into a transform plane and extract a deblurring function . Which can cancel out much (but not all) of such things as camera motion. And perform such tricks as reading those license plates on speeding cars.

There are now zillions of exciting techniques which use digital image processing. We may look at some of these in future columns. But the first of the two techniques I feel are by far the most important involves…

Gamma Correction

The eye acts as a log, rather than a linear device. And deep down inside, most display schemes are also quite nonlinear. As figure three shows us, the Gamma curve for any imaging system relates how the expected input gray levels actually appear to your eye at the output.

The process of "fixing" a gamma curve gets called Gamma Correction . On a video display, nonlinearities are purposely introduced to attempt to cancel out such nonlinearities as the square law response of most electron beams to a control voltage. In color work, the strengths of each individual beam are also carefully adjusted to make each color appear to be equally bright. Even if the color phosphors used have different sensitivities. As does your eye's response.

If at all possible, you want to do your gamma correction in some way that does not cut into the number of grays you have got available. But if it simply can't be helped, digital image processing can get applied to gamma correct your display. It can do this by redefining gray levels, trading off a lot of nonlinear grays for fewer and more linear ones.

All of today's laser printers have inherently nonlinear gamma curves. This happens because a round dot is used which has to be larger than the intended square pixel it is supposed to completely and flawlessly overwrite. Thus, in a black write system (such as the Canon SX) where the laser places down black dots, typical gray levels usually end up darker than you asked for. Especially the lightest ones.

The PhotoGrade system used on the Apple LaserWriter G uses a digital image processing to trade off its gray levels for a more linear gamma. We saw some details on the PhotoGrade halftoning process last month. As a specific example, at *106 DPI* Apple's PhotoGrade system has *128* gray levels available. A total of *61* of these are often used for gamma correction. The gamma correction gets done by redefining lots of really dark grays and a few of the mid range grays. The net result is the remaining *67* distinct and fully Gamma corrected grays.

The PhotoGrade system offers you three calibration options. The options compensate for your particular choice of toner, density settings, humidity, and so on. On a calibration, a coarse and a finer halftone square are put down for typical gray levels. This is done for three different pages. You then pick the page you like the best. The internal code does a predefined Gamma correction for you.

Additional details on PhotoGrade processing appear in my GEnie *PSRT #451 LASGCAL.PS* and over in *#388 LASGNOTE.TXT*. Also quite handy is a *#R023ll/A* LaserWriter IIg Printers Developer Notes from *APDA*.

Histograms and Their Equalization

Those photo darkroom technicians and artists have lots of secret tricks they employ to explore the incredible
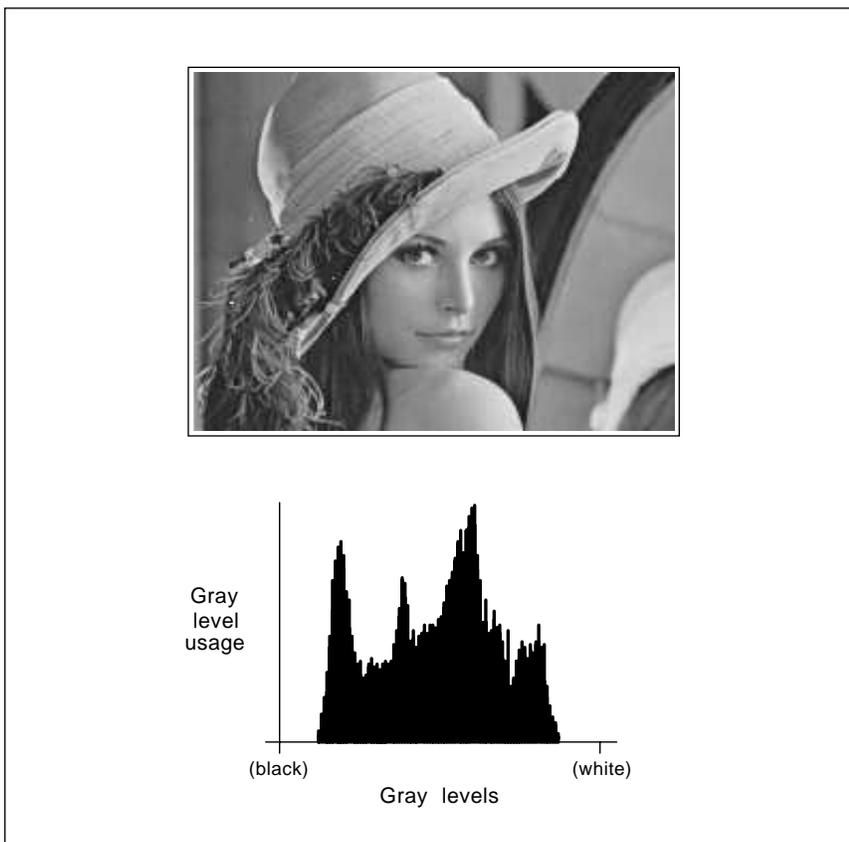
Fig. 4 – THIS STOCK "LENA" DIGITAL IMAGE appears rather "weak" or "low in contrast". A glance at the histogram clearly shows why. There are no dark blacks, no lighter whites, and the few remaining grays cluster in or around the two prominent peaks.

dynamic range of most photo film. By lengthening or shortening all their exposures, they can make all of their prints darker or lighter. By printing on a "soft" paper, they can reduce their dynamic range and contrast. Or can increase it by using a "hard" paper. Or even eliminate it entirely with a litho photo paper.

Even more sneaky is dodging and burning . With dodging, you put your moving and out-of-focus hand or a dodging paddle between the enlarger and the area being printed. This holds back your light in a selected area and makes that area lighter than normal. Which lets you pull details out of any dark or "muddy" areas of your neg.

With burning, you hold an opaque mask having a small, ragged, out of focus, and rapidly moving hole in it between your enlarger and the print paper. Burning lets you darken your highlights and extract details from underexposed areas.

By now, most of you have seen those spectacular Navajo slot canyon photos. Most any southwest calendar should include at least one example. And Arizona Highways will be happy to sell you bunches of them. These incredible prints carry dodging and burning to an extreme, using multiple exposures and twenty or more very precisely aligned dodging masks to dramatically bring out the subtlities of color and texture.

Sorry, but if you go to the bottom of one of these slot canyons like I have, you'll find them to be – mostly dark. What you are viewing on your final slide or print is highly spectacular darkroom art, rather than any human viewable reality.

Digital image processing can be used to imitate these darkroom tricks. And getting things right on gets even more important with digital images, because you will always be severely limited by both the available dynamic range and laser resolution.

The first step in correcting a digital image is to find out what was wrong with it in the first place. To do this, you run a histogram . A histogram is simply a vote on how many of the grays get used how often. Figure four shows us the stock and well known Lena digital image. If all has gone ok with the **Electronics Now** prepress ops that are beyond my control, this photo

should appear slightly "weak" or low in contrast. Flat.

That histogram underneath Lena clearly shows us why. Those lightest and darkest grays are not used at all. And most of the rest are bunched in two clearly defined peaks.

A digital image processing method known as histogram equalization will let you perform a magic dodging and burning which can often dramatically improve your results. If figure five made it through prepress the way I hope it will, you should see a much higher contrast and greatly improved Lena with lots more "snap".

To do your histogram equalization, you try and spread all of your pels around such that each gray gets used nearly as often as any other . You can then selectively replace each pel with a lighter or a darker gray, adjusting your accumulated sum to spread out the total number of pels per gray.

In short, you'll do an absolutely perfect dodge and burn.

For instance, if you have *49152* pels in your image and use *256* gray levels, you redefine your grays to get about *192* or so pels per gray level. A simple accumulated running average does the job for you. Full code details in my digital image tools on GEnie *PSRT*, especially *IMAGEKIT.PS.* As you can see in figure five, nearly all of those available grays are fully and uniformly used. Or nearly so.

Very conveniently, if you do some histogram equalization at *256* gray levels, it should also work with fewer quantization bits or any reduced gray levels. Thus, once you have done a histo equalization, even reduced gray scale pictures should be dramatically improved. Even more so.

By doing a histogram equalization, you can print "auto shopper" quality images on any unenhanced *300 DPI* laser printer. You'll have the best luck with this by using a *75* line *30* degree screen with *18* grays, or else a *70* line, *45* degree screen with *19* grays.
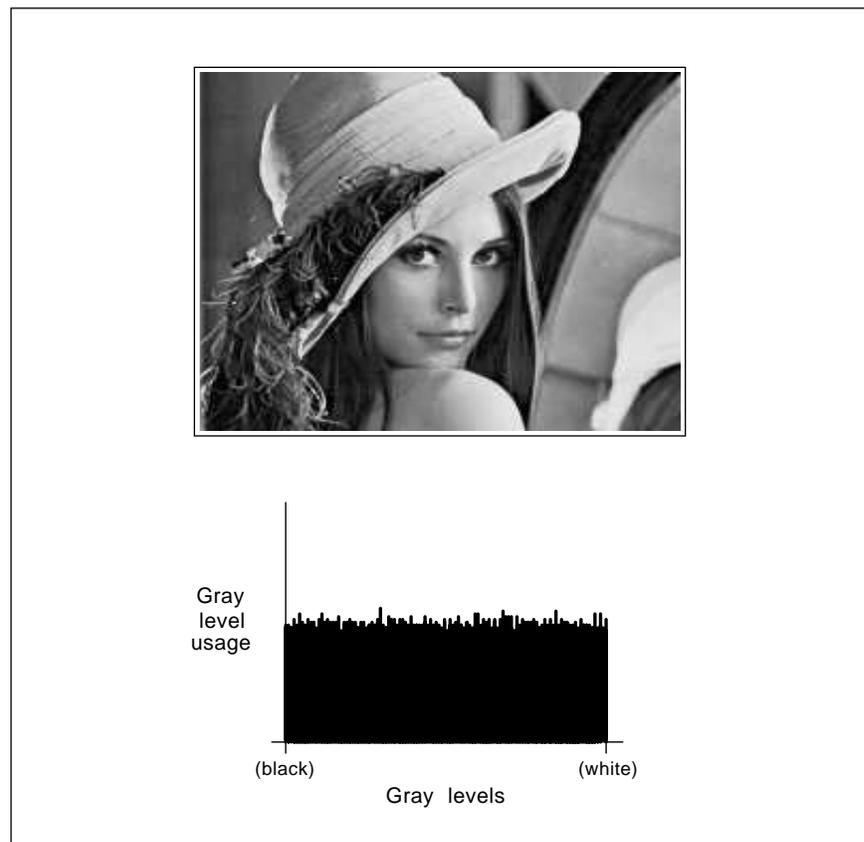
Fig. 5 – HISTOGRAM EQUALIZED "LENA" DIGITAL IMAGE has considerably more "snap" and much higher contrast. The histogram shows all gray values are in full use. A histo equalization is the same as a perfect photo "dodge and burn". The quality can be further improved by gamma correction.

Figures four and five are available as *PSRT* files *#463 LENA.PS* and my *#468 LENAHIST.PS*

Any time you are limited in your gray levels, good histo equalization becomes absolutely essential. We saw more details on electronic halftoning in last month's column.

Semiconductor Chip Houses

I have been meaning to do some resource sidebars that give you most integrated circuit manufacturers, or at least the more hacker friendly ones. Since there's so many of them, we'll need several sidebars to do the job right. So, Actel through Fujitsu will appear this month, and I'll show you the rest of them when and as we can get to them.

Some data books are free. Others have "optional" pricing depending on whether the sales person likes you or whether any of the covered chips are currently being promoted. For others, just about everybody has to pay the going rate.

Your best bet is to first request a short form catalog, a price list, and their technical literature and ap note index. These are all usually both free and immediately available.

Be sure to use your laser printed letterhead or a professional sounding telephone request.

New Tech Lit

Data books for this month include the Opelelectronic Products Catalog from Quality Technologies . This used to be the old GE/Harris opto line.

From Advanced Linear Devices , a Product Databook on linear timers, op amps, and comparators.

From Signetics/Philips , a new data book on CMOS Sequencer Solutions . And from Hitachi , a Semiconductor Devices for Communications data book. Included are lots of telco and cellular radio devices.

Our two brand new labor-of-love newsletters for this month do include WeatherSat Ink and the Geo-Monitor . The first is on weather satellite image reception; the second on earthquake monitoring and prediction.

Over in our neat mechanical stuff department, a free sample of a laser machined plastic is available from *KMC*. And an incredible catalog from Outwater Plastics . These folks are

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SEMICONDUCTOR RESOURCES (I)

Actel
955 East Arques Avenue
Sunnyvale, CA 94086
(408) 739-1010

Advanced Linear Devices
1180 F Miraloma Way
Sunnyvale, CA 94086
(408) 720-8737

Advanced Micro Devices
PO Box 3453
Sunnyvale, CA 94088
(800) 222-9323

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

Altera
2610 Orchard Parkway
San Jose, CA 95134
(408) 984-2800

Analog Devices
PO Box 9106
Norwood, MA 02062
(617) 329-4700

AT&T
555 Union Blvd
Allentown, PA 18103
(800) 372-2447

Brooktree
9950 Barnes Canyon Road
San Diego, CA 92121
(800) 843-3642

Burr-Brown
6730 South Tucson Blvd
Tucson, AZ 85706
(602) 746-1111

California Micro Devices
215 Topaz
Milpitas, CA 95035
(408) 263-3214

Catalyst Semiconductor
2231 Calle de Luna
Santa Clara, CA 95054
(408) 748-7700

Cherry Semiconductor
2000 South County Trail
East Greenwich, RI 02818
(401) 885-3600

Cirrus Logic
1463 Centre Pointe Drive
Milpitas, CA 95035
(408) 945-8300

Crystal Semiconductor
PO Box 17847
Austin, TX 78760
(512) 445-7222

Cybernetic Micro Systems
3000 Highway 84
San Gregorio, CA 94074
(415) 726-3000

Cypress Semiconductor
3901 North First Street
San Jose, CA 95134
(408) 943-2600

Dallas Semiconductor
4401 South Beltwood Pkwy
Dallas, TX 75244
(214) 450-0400

EG&G Reticon
345 Potero Avenue
Sunnyvale, CA 94086
(408) 738-4266

Elantec
1996 Tarob Court
Milpitas, CA 95035
(408) 945-1323

Exar
PO Box 49007
San Jose, CA 95161
(408) 732-7970

Exel
2150 Commerce Drive
San Jose, CA 95131
(408) 432-0500

Fujitsu
3545 N First Street
San Jose, CA 95134
(800) 642-7616

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laboring under the delusion that they are now in the store display fixtures business. In reality, they offer lots of useful new electronic and prototyping hardware at unbeatable prices. Not to mention off-the-wall and on-the-wall ideas. They even stock Grecian urns for writing odes on.

For the two key books on all of the fundamentals of digital integrated circuits, try my CMOS Cookbook and

TTL Cookbook , either by themselves or as part of my Lancaster Classics Library . Per my Synergetics ad.

As usual, we've gathered many of the resources mentioned together into either Names & Numbers appendix or in the Semiconductor Resources (I) sidebar. Do be sure to check these out before you use our no-charge tech helpline or calling for a free hacker secrets brochure. ❖

Don Lancaster's
Hardware Hacker

Distant FM reception
UFO resources listing
TV/FM booster circuits
UHF & VHF amplifiers
Pseudoscience research

November, 1992

J udging by the letters and my helpline calls, there's clearly a bunch of interest in those alternate science and pseudo science topics among many of you **Electronics Now** subscribers. Some because you genuinely believe, and others because you (as I) find these subjects make fascinating reading.

Your centermost two secrets to all hardware hacking are a curiosity and a sense of wonder. Which explains why such widely ranging subjects as the *Powder & Bulk Solids* trade journal, specialty hardwoods, Grecian urns, Buckeyball research, rubber iguanas, and tinaja questing all are vastly more mainstream to hardware hacking than they would appear at first glance.

I come at all this from a traditional and formal engineering background. I strongly believe in such things as all of the laws of thermodynamics, and in simple and verifiable experiments.

I also realize that getting relevant and accurate results in the lab end up nearly always the exception, rather than the rule. I am a highly skeptical inquirer, albeit one who very much loves to run a stick over the bars of establishment cages. And one who always likes to encourage people to think things out for themselves.

As a researcher, I feel there is a fuzzy something out there I'll call *the edge*. This side of the edge, things (at least to me) seem "probably true". On the far side of the edge, things appear "probably false". To determine which side of the edge a subject currently lies on, I'll often first apply the laws of physics and the ability to actually experiment. Second, I'll ask what the laws of statistics have to tell us on the odds of an occurence and on the data sample sizes. And third, I'll try to apply Ockham's razor to find out if there is a simpler explanation or a more likely underlying cause.

After that, I'll ask some crucial cultural questions. Such as: Where is the cash flow? You always follow the money. Who benefits? Who loses? What psychological or other needs are being filled in all those involved?

Could this make a good hoax?

Were magic cookies involved? Are there any personality disorders? What irrelevant links are there to religions, conspiracies, or any politics? Has this ground ever been plowed before?

Do things seem *slightly* ratty? Is there "just enough" noise, loose ends, conflict, and missing pieces to fit the way the real world actually works? Are all of the tees dotted and the eyes crossed, rather than vice versa? Are

results shown to eight decimal place precision conspicuously absent?

Finally, I'll try to apply my "likes water, looks like a duck, and quacks like a duck" filter. Especially if eggs are about to be laid…

Thoughts on UFO's

On to today's story. You see, I was abducted by a UFO enthusiast. Yup, a close encounter of the zeroth kind.

Actually, I guess I did pay him to be

(A) Standard FM air dielectric test dipole.

(B) "On the wall" FM twinlead Tee.

(C) Seven element FM Yagi array.
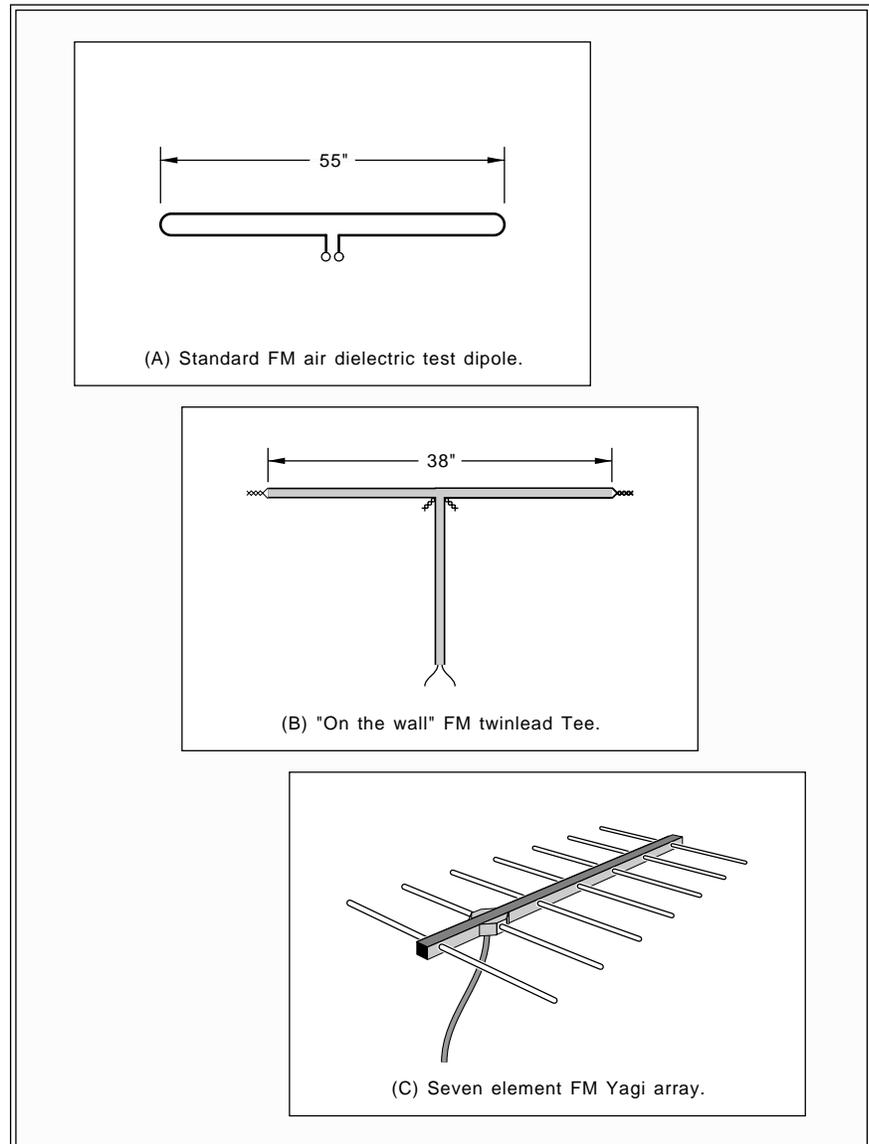
Fig. 1 – SOME POPULAR FM antennas based upon ordinary dipoles.
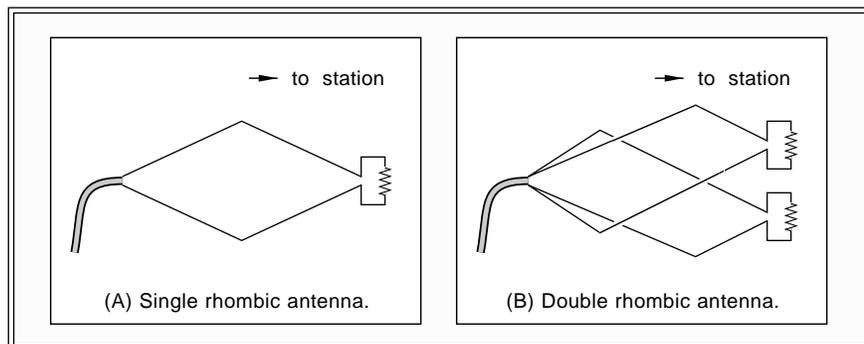
Fig. 2 – THE RHOMBIC FM ANTENNA is humongously large, but does offer exceptionally high gain over a quite a wide bandwidth.

abducted. Mike Sherlock runs a great (and one incredibly low cost) top secret hideaway escape in the most remote portion of New Mexico's wilderness outback. The *Black Range Lodge*.

Mike is a sometimes Hollywood type who has gathered great heaping bunches of footage into what, uncut, is twelve hours of video tentatively titled *The UFO Marathon*. He is now in the process of editing down and securing the rights for its eventual release.

This material ranges the gamut from professionally produced and largely impeccable network-tv footage on down (wayyy... on down) to grainy black and white home videos from southern Florida box-only addresses. Whose special effects wouldn't even rate the cutting room floor of a 1950's grade Z sci-fi horror flick.

For once, I am at a loss for words. To call this "lore" is condescending. But calling it "evidence" seems too strong. Besides, that word "evidence" has vastly different meanings to an engineer, a lawyer, or a priest. So a neutral working definition: The UFO *resource base* is the sum total of the available words and images on this topic that are reasonably coherent and more or less relevant.

After sitting through a full twelve hours of video and then some, I have come to three tentative conclusions:

(1) The scope, breadth, and depth of the UFO resource base is now very much larger than I thought it was.

(2) The potential credibility of at least a significant subset of the UFO resource base appears to be higher than I thought it would.

(3) The current UFO resource base does represent a multimillion dollar *industry* that now employs thousands on an international basis. Both in and out of government.

That *UFO Magazine* appears to be the leading industry trade magazine. Your highest profile watchdog group is the *Skeptical Inquirer*. Your finest

directory is the new *Almanac of UFO Organizations*. It's written by David Blevins, published by *Phadera*, and stocked by *Arcturcus*, among others.

This is sort of a combined *Thomas Register* and *Michelin Guide*. I'd give it a four ET rating.

Our resource sidebar for this month shows you many of the leading places to go for further info on UFO's and any related phenomena. Both pro and con.

And a related contest…

As for our contest this month, just answer the question *Are we alone?* in 70,000 words or less and send it in to me. There'll be dozens of my usual *Incredible Secret Money Machine II* books, along with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the best of all.

Be sure to send all of your entries directly to me here at my *Synergetics*, rather than over to **Electronics Now** editorial. The entry deadline will be extended for any responses arriving from fifty light years or more away. Especially if they don't have tinajas.

Long Distance FM

We have had quite a few entries in our ultra long distance FM reception contest, so I thought we might review what can and cannot be done here.

With most any problem, there are usually both technical and cultural solutions. Judging by the absolute outrage *Post-Newsweek Cable* has caused locally by dropping all quality FM station coverage here in the Gila Valley, I do suppose such things as petition drives, suitably annoying the politicians, rattling the Corporation Commission's cage, encouraging the competition, or promoting translators could be effective.

So would changing your listening habits. And newer FM transmission schemes are in the works with much higher effective ranges, especially for stereo. But, in voting with my wallet, I simply prefer to no longer send any of my hard earned cash to those who I feel are clearly biting the hand that feeds them.

At any rate, broadcast FM stations lie in the frequency range of 88.1 to 107.9 Mhz on channels spaced 200 kHz apart. This is in a portion of the radio spectrum where thermal noise
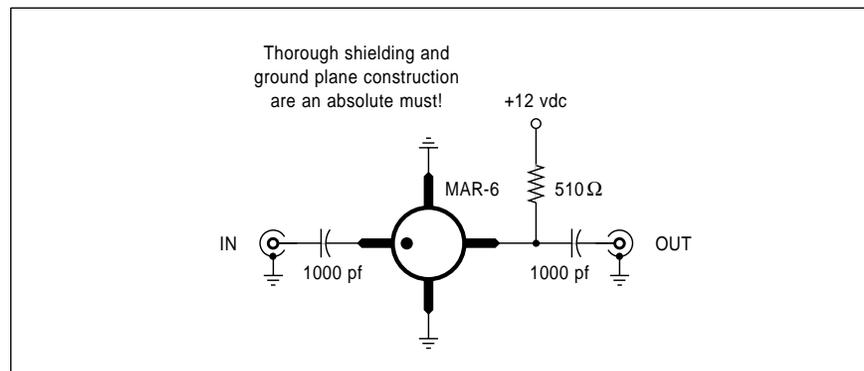
Fig. 3 – MINI-CIRCUITS LABS offer a number of ultra low cost and easy to use broadband VHF/UHF amplifiers and kits. This circuit forms an FM booster with a 20 decibel gain and a 1 decibel noise figure. Input and output impedances are 50 ohms. Pre-filtering must be used to reject any strong out-of-band signals.

ultimately limits distance reception. Although daytime ignition noise can become dominant in urban areas.

Your FM reception of any nearby stations can become complicated by *multipath* and the *picket fence* effects where the signals bounce around any nearby hills and structures. Steel or wire present in buildings also can act as partial to total shielding. And any strong nearby station that's close in frequency to a weaker distant one can also give you fits.

Urban solutions tend to center on smaller directional antennas having deep nulls, in shielded transmission lines that are carefully matched, and in good receiver selectivity.

For remote rural areas, plain old signal strength will usually be your main problem. But no matter where you are, the higher you can get your antenna and the nearer you can get to a straight shot at the transmitter, the better your resultant signal.

FM signals are often horizontally polarized and best travel line of sight. In my Basin-and-Range Southwest, it is typical to have many stations come booming in on most any mountaintop from hundreds of miles away. On the cheapest receivers with zilch for an antenna. But distant reception can get hairy fast if you lose line-of-sight.

Many contest entries did suggest putting an antenna on the mountain and then rebroadcasting somehow.

Perhaps as a *passive repeater* (two unpowered back-to-back antennas that often works surprisingly well in special instances); as some *active repeater* (isolated rebroadcasting on the same frequency to prevent feedback); as a *translator* (low power rebroadcasting on some other frequency); or with an *optical link* (which sends out highly directional modulated light pulses). Sadly, these don't seem too practical for me, since either going clandestine or hassling the Forest Service or BLM would be involved. There would also be lightning and power problems.

The *gain* of an antenna is simply how much better it works in its best direction than a comparable *isotropic* antenna that accepts signals equally well from any direction. Raising the gain of your antenna by a mere three decibels is the same as having the station *double* the transmitted power.

The standard baseline FM antenna is called a *dipole* and is shown in figure 1-A. The dipole has a figure-8 pattern which gives it a peak gain of around two decibels above isotropic.

The dipole can be reduced in size by using twinlead with its 0.7 velocity factor. Our figure 1-B shows you the standard hang-it-on-the-wall indoor FM Tee antenna. But don't forget this antenna has a "figure-8" pattern with nulls along its length, so pick your wall accordingly.

If one dipole is good, then more of them should be better. A group of dipoles form an *array*. It turns out that you do not have to power all of your dipoles. Some of them can be *passive* or *parasitic* elements. Usually, the first parasitic element will go behind your dipole and is called a *reflector*.

One or more additional parasitic elements can go in front of the dipole and are called *directors*. Usually, there is only a single reflector but multiple directors. The directors are usually shorter than the reflector. These two clues tell you which way to initially "point" any antenna.

Figure 1-C shows you one popular arrangement for active and passive antenna elements called a *Yagi*. Yagi antennas are compact, have high gain and a stong front to back ratio.

Yagi antennas can be designed for one single station, for the entire FM band, or for all of FM and television combined. Broadbanding is done by changing the sizes, lengths, and the interpositioning of the elements. All other things being equal, the narrower the bandwidth, the higher the gain.

Ferinstance, a single channel, five element Yagi might have a gain of 11 DB. That same antenna broadbanded may have only 5 DB of gain.

Thus, a single station FM Yagi will usually deliver a stronger signal than will an "all band" tv antenna.

Since they obviously would have to be expensive special orders, you'll normally build your own custom cut Yagi antennas. One secret to narrow band and high gain is to use *very thin* directors. I've posted an FMYAGI.PS design program to my *GEnie* PSRT. We may look at this some more in a future column. Let me know if you are interested.

Yes, antennas can be stacked. But doing so often isn't worth the hassle. The second antenna at best adds only three decibels to what you've already got. And without proper impedance
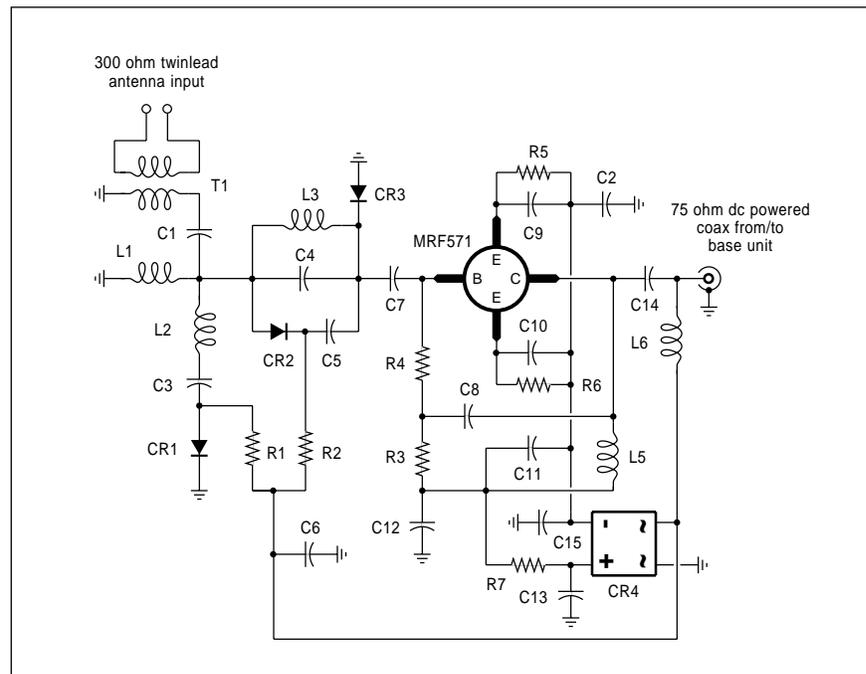
Fig. 4 – APPROXIMATE SCHEMATIC for the Radio Shack 15-1108 TV/FM booster antenna unit. The polarity of the dc power routed up the coax decides if the FM trap will be switched in or out. The low cost Motorola transistors used have an 8 Gigahertz bandwidth and an FM noise figure of 0.4 Decibels!

matching, you can actually *degrade* your signal.

The *Radio Shack* 15-1636 is a low cost Yagi-like antenna having three active elements, three directors, and a reflector in a reasonably compact $17 design. This can be a good choice for all but the deepest of fringe areas. But it looks to me like they cheated a tad on the overall size.

While Yagi-style FM antennas are often the simplest and best, there is another Hacker alternative. This one gets called a *rhombic* antenna, and is just a parallelogram of wire sent either around or across your room. Figure two shows details.

Intuitively, a rhombic has a much larger area and thus (when properly designed, properly aligned, and used in a proper location) intercepts more signal for a potentially higher gain.

Large (70 foot) FM outdoor double rhombics can reach a mind-numbing 28 decibels of gain! Broadband, yet.

But there is so much that can go wrong with a rhombic design and so much cut and try is involved, that you may want to save this as a last resort. And then only when there are no strong local stations.

One useful paper on these rhombic antennas is *Improved Antennas of the Rhombic Class* run in the March 1960 *RCA Review*. You also might want to check *Try a Rhombic FM Antenna* in the *January* 1982 issue of *Audio*.

More info on Yagis, rhombics, and antennas in general can be found in any of a number of college or ham texts. The ARRL's *Antenna Book* or the *Antenna Engineering Handbook* by Jasik are typical classics.

Reception of FM signals can end up more art than science. So, if you are only interested in one particular FM station and all else fails, try black magic. Change the antenna direction and position to try and find a local hot spot. You might try extra pieces of conductor in or near your antenna. In one trial, I found that shorting the antenna cross feed with an aluminum yardstick dramatically improved the results for one target station.

Some FM stations add a vertical or a circular polarization to their pattern to improve their mobile reception. So, a non-horizontal antenna sometimes may work better than you would first expect. Try it and see. Should you be mainly interested in one station, call them and ask what pattern they use.

One final trick to deal with a noisy FM signal is to reduce its bandwidth. The quickest and simplest way to do this is to switch from stereo to mono. This halves your bandwidth and thus reduces your noise by three decibels. Some advanced car radio circuits do this automatically.

It is also possible to use low pass filters (such as the treble control or messing with your loudness curve) to further reduce your received noise. While, of course, losing the station's high frequencies as well.

We better throw in some obvious safety warnings here: Outside and/or high antennas must receive lightning protection. Antennas can kill you if you hit a power line when installing one. And any ladders and heights in general could cause deadly falls.

FM Booster Amplifiers

Will an FM "booster" amplifier help us at all? Can't we simply make the received signal louder?

For a number of reasons, booster amplifiers can be a disappointment to an outright disaster. But, with some care, boosters do have their uses.

For any chosen station, any given receiving antenna at any given place pointing in any given direction, there will be so many microvolts of signal appearing at your antenna terminals. There'll also be so many microvolts of *thermal agitation noise* that appears across the antenna terminals. At FM and higher frequencies, the amount of this rural noise usually gets set by the *temperature* of the antenna, and little else. At least for a given bandwidth.

The ratio of these two voltages is known as the *signal to noise ratio*. A S/N ratio that can produce 20 DB of limiter *quieting* is needed to give you "good" FM reception. Anything less gets progressively noisier.

For a given fixed bandwidth and reception scheme, *there is no known amplifier or other electronic method to improve the input signal to noise ratio across your antenna terminals!*

All the booster amplifier can do is amplify *both* the signal *and* the noise together. Thus, if your input signal to noise ratio is too low, there is *no way* that *any* amplifier can help you.
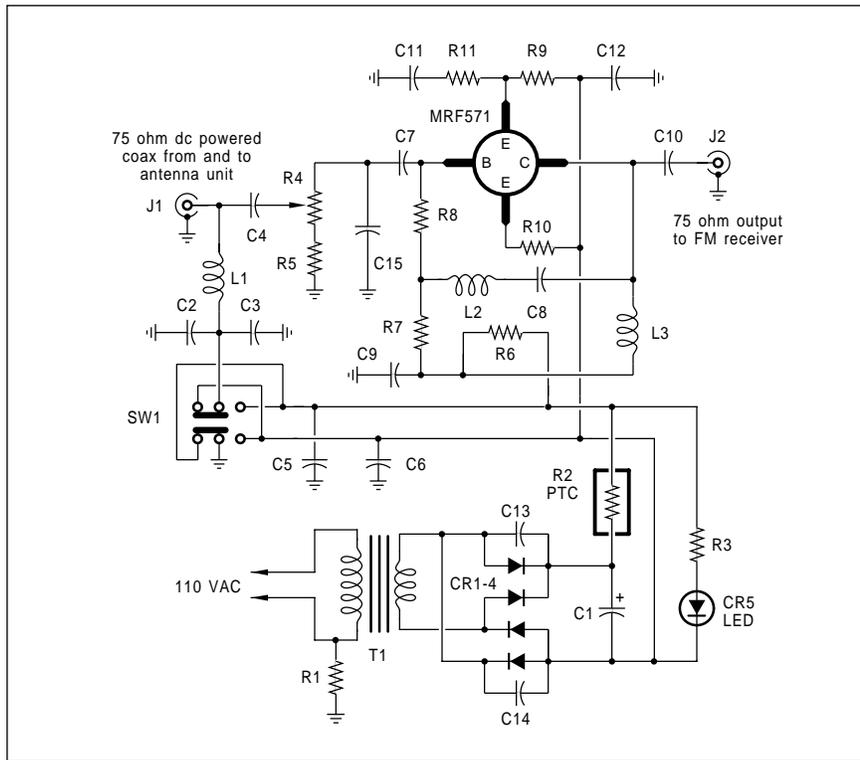
Fig. 5 – APPROXIMATE SCHEMATIC for the Radio Shack 15-1108 TV/FM booster base unit. Switch SW1 remotely activates the FM trap. Be careful not to mix up your cables; the dc power on the coax could cause receiver damage.

Put another way, you just cannot amplify a signal that is not there.

Further, any booster amplifier will add its *own* noise and always *lower* your signal to noise ratio. The extra amplifier noise over and above the thermal background is known as the *noise figure*. With care and using the latest of UHF transistors, an FM first stage noise figure under half a decibel (around five percent amplitude) can easily get done. On the other hand, throw in any old el-cheapo transistor, and your FM noise figure can easily get outrageously bad.

Worse yet, if there are any strong signals that are also being amplified, these can overload your booster amp, splattering themselves all across the band and creating *spurs*. It's real easy to convince yourself that your booster amp gave you "lots" of new stations; in reality it is just the crossmod from strong local signals.

Finally, quite a bit of design effort has gone into the front end of most premium FM receivers. Unless your booster has a *better* design than your FM receiver, it is almost certain to degrade, rather than improve your reception. Most of those el-cheapo bargain boosters found in the yuppy catalogs will often make your signals *more*, rather than less noisy.

So, what good is a booster? A high quality and properly designed booster can make up for transmission losses down long cables. They can present a more standard and a better matched load for your antenna. They can make up for a cheaper receiver front end design. Or for standing waves and some impedance unbalances. And they are particularly useful when you want to drive two or more receivers from one antenna at the same time.

Figure 3 can show you a simple broadband hacker VHF amplifier you might like to experiment with. This uses a low cost integrated amplifier from *Mini-Circuits Labs*. Since this is a very wideband circuit, you do have to watch for saturation effects from any interfering signals. And thorough shielding is a must. Naturally, adding resonant circuits and limiting your bandwidth can give you *much* better results for the frequencies you are interested in. But that sure makes the design a lot more complicated.

Radio Shack has a newer 15-1108

UFO RESOURCES

Arcturcus Books PO Box 831383 Stone Mtn, GA 30083 (404) 297-4624	**Lindsay Publications** PO Box 538 Bradley, IL 60915 (815) 935-5353	**Strange Magazine** PO Box 2246 Rockville, MD 20847 (301) 881-3530
Black Range Lodge Star Rt. 2, Box 119 Kingston, NM 88042 (505) 895-5652	**Mutual UFO Network** 103 Oldtowne Road Seguin, TX 78155 (512) 379-9216	**UFO Audio/Video** PO Box 342-M Yucaipa, CA 92399 (714) 795-3361
Borderland Sciences PO Box 429 Garberville, CA 95542 (707) 986-7211	**ParaNet Info Service** PO Box 172 Wheat Ridge, CO 80034 (303) 431-8796	**UFO Books** PO Box 1053 Florence, AZ 85232 (602) 868-4273
Eden Press Box 399 Careywood, ID 83809 (208) 683-2439	**Phaedra Enterprises** PO Box 1241 San Bruno, CA 94066 (415) 359-0432	**UFO Database** PO Box 1053 Sunland, CA 91041 (818) 769-2917
Genesis Publishing PO Box 25962 Munds Park, AZ 86017 (602) 955-8034	**Search Magazine** PO Box 81 Rosholt, WI 54473 (715) 344-5585	**UFO Magazine** PO Box 1053 Sunland, CA 91041 (818) 951-1250
High Energy Ent. PO Box 5636 Security, CO 80931 (719) 475-0918	**Skeptical Inquirer** PO Box 703 Buffalo, NY 14226 (716) 636-1425	**UFO News Service** Rt. 1 Box 220 Plumerville, AR 72127 (501) 354-2558

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broadband TV/FM booster that uses a pair of exceptionally hot new *Motorola* MRF571 transistors. do These have an eight Gigahertz cutoff frequency and an FM band noise figure of only 0.4 decibels! Approximate schematics for the antenna and base units are shown you in figures four and five.

The antenna unit is made up from a switchable FM trap (just what we do *not* need!) and one fairly low gain amplification stage and cable driver. The twinlead serves two purposes: It routes DC power up from their base station and downlinks your partially amplified RF signals. The polarity of the DC power decides whether the FM trap gets switched in or out. Ordinary silicon diodes do the switching.

You might like to experiment with completely eliminating the FM trap. I don't trust its being there at all, even in its supposedly "off" position. To do this, you could try removing L1, L2, R2, and CR2, while replacing L3 with the shortest possible jumper.

The base station is made up of a power supply and another transistor which acts as a line driver or as a distribution amplifier. There's also an adjustable attenuator to optimize the signal levels.

New Tech Lit

Motorola has announced several really exciting new chips. Especially the new MC144143 single chip *Closed Caption TV Decoder* and their new DSP56401 *Digital Audio Transceiver.*

We do have a collection of unusual publications this month. Tony Patti still prints his *Cryptosystems Journal* that's big on cryptography and chaos topics. And the *Journal of Computer Game Design* is a great labor-of-love newsletter by Chris Crawford.

Two unique music newsletters are *Experimental Musical Instruments* and *Guitar Digest*. And *Solar Mind* newly offers several "Holistic Approaches to Technology and Environment."

The folks at *Lindsay Publications* are offering a number of new titles. These include a turn-of-the-century reprint on *Large Induction Coils*, and a new one on do-it-yourself *Lightning Bolt Generators.*

I've been self-publishing quite a few titles these days using my new *Book-on-demand* process. Included are my *Hardware Hacker* reprints II & III, my *Ask the Guru* reprints I, II, & III; my *Blatant Opportunist* I, the new *Resource Bin I*, and my *LaserWriter Secrets* book and disk combo. ❖

Don Lancaster's
Hardware Hacker

December, 1992

So many exciting new hacker opportunities have come down this month that I do not even know where to start. We seem to be moving into a boundless new era of hardware hacking.

Before we begin, though, there've been a few recent helpline calls over some really ancient history which we should go over one final time…

Follow that current!

Which way does the current travel in any electrical or electronic circuit? Many years ago, one of the electrical pioneers ventured his wild *guess* that *electrical current always goes from the negative to the positive terminal in an energy source and from positive to negative in an energy sink.*

It took over a century to verify, but the guess turned out to be correct. At least for certain solid state circuits at least some of the time.

To this day, this guess is called the *conventional* electrical current, and appears in figure one. Conventional current is the *only* standard taught in *all* university and *all* graduate level engineering courses, gets used by *all* physicists, and accepted by *all* large electronic firms worldwide.

Conventional current is shown in the direction of the arrows on *all* the standard electronic symbols. Even the IEEE tie clasp and cuff links strongly restate the conventional current. So does the righthand generator rule and lefthand motor rule.

Yeahbut, just which way does the current *really* go? Well, a glib answer for the new age nineties is "any way you want it to".

In semiconductor loads, the current direction gets decided by the majority carriers. In any PNP transistor or any P-channel MOSFET, conduction is by hole carriers, and the current does in fact go in exactly the same direction as the conventional current. In N-type devices, the current is the opposite of the conventional current direction.

So what is the problem? And why am I standing here whipping this long dead horse?

Way on back during World War II, PNP vacuum tubes were very few and far between. Come to think of it, they still are. Because of this, the military introduced the concept of the *electron current* to explain how a vacuum tube works. And many trade schools and lower level textbooks continued this practice into the fifties and sixties.

Which led to the absurd result that a few hackers, technicians, and much of the hobby press had their currents heading in one way, while all of the engineers, physicists, and the rest of industry had their currents heading in the exact opposite direction.

The bottom line: If any individual or any textbook still tries to teach you electron current, they are ripping you off. They are also doing you a serious disservice that will lead you to untold confusion and latter day hassles.

Neither electron nor conventional current is correct all of the time. The overwhelming majority of industry and professional level training *always* goes with the conventional current.

Among the other reasons, because there is no compelling reason not to.

Just what would it take to convert industry over to electron current? For openers, extremely frigid conditions in a distinctly unpleasant locale. Or

some words to that effect. Even then, I would not expect to see this happen until a few weeks after the Ayatolla's Bar Mitzvah.

When in Rome, go with the flow. Or too many cooks gather no moss. Er, something like that there.

Navicube Update

Way on back in *Hardware Hacker #7*, we looked at the *Navicube*, a 3 inch and a 10 dollar cube that always knew where it was and which way it was pointed. Well, we still don't have $10 Navicubes, although I do expect some Korean toy manufacturer or two kids in an Iowa basement to shortly come up with a really good one.

A lot is happening with Navicubes, both evolutionary and revolutionary. An update summary of Navicube info appears as our resource sidebar.

Today's popular approaches to the Navicubes include the GPS satellite system, fluxgates, real gyros, laser gyros, accelerometers, and a pair of brand new piezo gyros.

The GPS global positioning system is going great guns. Their eighteenth satellite is now in orbit, and Russian and ECC competing systems are now being established. Receiver prices are in free fall, and the $500 barrier has
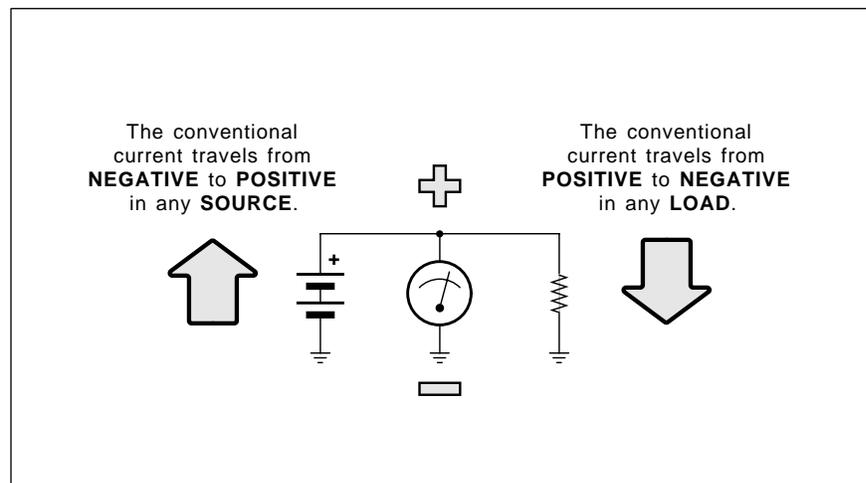
Fig. 1 – THE CONVENTIONAL ELECTRIC CURRENT goes from negative to positive in any energy source and from positive to negative in any energy sink. This is THE standard used by all graduate engineers, physicists, electronic symbols, and industry worldwide. It even appears on the IEEE cufflinks.

(A) The Systron-Donner GyroChip is based on two coupled tuning forks. The Coriolis force from any rotation around the vertical axis changes the phase and amplitude of the synchronously demodulated output signal.

(B) The Murata-Erie GyroStar is based on carefully controlled vibration modes in a triangular piezo element. Any relative clockwise or counterclockwise rotation changes the phase and amplitude of the output signals.

Fig. 2 – NEW DEVELOPMENTS IN PIEZO RATE GYROS should eventually lead to low cost Navicube solutions. A rate gyro tells you how fast you are now turning. Integrating the turn rate (summing through time) gives you the current direction.

recently been broken.

GPS World is your foremost trade journal. They've also just started up a new *GPS World Showcase* shopper. As before, the *Journal of the Institute of Navigation* is the finest Navicube technical resource.

Although *Rockwell* is still the most obvious source for the GPS chipsets, *Hewlett Packard* has just developed a new single chip GPS front end. While too early for a part number, several details now appear in *Microwaves & RF* for August 1992. I expect cheap new GPS parts real soon now, from several obvious sources.

North sensors are best done using fluxgate magnetometers. Radio Shack has a cheap one in their car compass,

and *KVH* sells expensive commercial units. We have seen several fluxgate construction projects and references in those *Hardware Hacker II* reprints. Naturally, any magnetic sensor gets confused by nearby iron.

Many hackers still labor under the delusion that Hall Effect devices can be used as compasses. Well, possibly they can, but fluxgates are *thousands* of times more sensitive.

One exception is the very low cost *Dinsmore* magnetic compass sensor. Sadly, its best possible accuracy is a crude 22.5 degrees.

Solid state accelerometers continue to drop in price, spurred on by newer automotive uses, especially airbags. While *Motorola* and *Micro Switch* are

the largest suppliers, the better priced and more innovative sensors are now provided by *Analog Devices*, *SenSym*, *IC Sensors*, and *NovaSensor*.

Your two best accelerometer trade journals are *Measurement & Control* and *Sensors*.

Note that you could integrate (sum through time) any acceleration to get velocity, and then integrate velocity to get the position. There is one huge technical hassle with accelerometers, though. This is called the "t-squared" problem. Any bias or similar error in acceleration ultimately piles up as a position error that is proportional to time *squared*.

Which means if you wait around long enough for your position, it is certain to be wrong. Accelerometers work best for short term uses, when they can be repeatedly recalibrated or reset from some other standard every now or then.

Your classic nav usually got done by using mechanical gyros. These are nothing but rapidly spinning masses, comparable to a toy gyroscope. These can be costly, cumbersome, and often involve precision elements rotating at very high speeds. Gyros are available surplus from *Fair Radio Sales*, *Radio Research Instruments*, and *AST Servo Systems*. One current manufacturer is *Humphrey Products*.

Yes, there are laser gyroscopes. A coil of fiber optic cable has coherent laser light beams routed through it in opposite directions which then can be phase compared. But not much seems to be happening here to drop the costs by the 1000:1 needed to make them a practical hacker tool. Good info on laser gyroscopes is available from the *IEEE Press* and from *SPIE*.

But our really big Navicube gyro news for this month involves a pair of brand new…

Solid-state rate gyro breakthroughs

A *rate gyro* is a special gyroscope which can tell you how fast you are *turning*. By integrating your rate of turn, you can get your direction. By combining this with some separately measured velocity, you can find your current position. And there will be no t-squared problem, since no double integration is involved.

Traditional rate gyros are available

from the sources of regular gyros we just looked at. A hackable and a low cost fluidic rate gyro was done a few years back by Doug Garner at *NASA*, which used an airstream differential cooling a pair of thermistors. But not too much seems to have come of this approach either.

A pair of new "solid state" rate gyros are now available. At least one of these promises to end up as a $5 component. Because these both use vibrating piezo structures, it is not quite correct to say that they have no moving parts. But these certainly are simple and rugged single piece units which involve zero rotating parts or precision mechanisms.

The first unit is the *GyroChip* by *Systron Donner* and shown in figure 2-A. This is a pair of back-to-back tuning forks machined from a single piece of silicon. The phase of your output signal gets determined by the *Coriolis* force caused by turning.

The seond piezo gyro is that new *Gyrostar* by *Murata-Erie*, and shown in figure 2-B. This is just a triangular piezo oscillator. The Coriolis force of rotation again changes the phase of the output signal in proportion to the rotation rate. This new scheme looks ridiculously simpler and vastly more elegant than the GyroChip design.

While both of these breakthrough devices have the potential to become low cost parts, the sample costs today are $300 for Murata's GyroStar, and a ludicrous $2000 for the GyroChip. Their support literature so far is also utterly dismal. But a new $5 Hong Kong ripoff is just about certain to quickly become available.

Assorted wonderments

Continuing this month's stunning new developments, here is a double handful of great new stuff...

Image Striking– Be sure to check out *Motion Imaging Processing: Striking Possibilities* in the August 1992 issue of *Advanced Imaging*. What we have apparently got here is a unique new concept and toolset for video, movie, and multimedia editing.

Put one frame of a small image in the upper left of your monitor screen. Next, move on down one pixel and one pixel to the right, and then repeat the process for the next frame in your

sequence. Continue until you have a diagonal smirp on down your screen, ending with a final full small image. While you are at it, show your sound amplitude for each frame along the top diagonal of the smirp.

What do you have? In one place and at one time, a display which lets you view the *temporal content* of a *time sequence* of multimedia or other video. In short, you can instantly look *forward or backward through time*, seeing the relationship between your current frame, its recent history, and its near future!

Looking at this "striking" concept slightly different, say you had a few feet of movie film. Cut the individual images apart so they have no borders. Stack them up and look *sideways* at their top and left edges. Once again, in one place and at one time, you can see what has happened and what is going to happen. An instant and real time plot of images versus time.

Naturally, the edges will only show you wildly abstract colors or patterns. But, with practice, those patterns can easily be read as to the scene, camera angle, panning, duration, sound sync, and much more.

A non-obvious ap: Quickly finding a buried sequence in a humongous video data base. It is sort of the video equivalent to that ISAM, or *indexed sequential access method* long used in data bases.

The editing, tweening, scanning, high speed access, and all the visual flow possibilities of this new scheme seem boundless.

Wavelets– The onslaught continues. A second book is now available and titled *Ten Lectures on Wavelets* by Ingrid Daubechies and published by *SIAM*, shorthand for the *Society for Industrial and Applied Mathematics*. While a first rate text, this is a very advanced math book that makes for

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#508 HACK58.TXT & #509 HACKFG58.PS

Reprint of *Hardware Hacker #58* from *Electronics Now*. Wavelets update includes optical applications, and new *Ten Lectures on Wavelets* book.

#494 EMERGOP2.PS

Reprint of *Blatant Opportunist #17* from *Midnight Engineering*. Wavelets are one of the eight hacker-friendly emerging tech opportunities reviewed.

#456 WAVELETS.PS

Reprint of *The Wavelet Onslaught* from the *Midnight Engineering Companion #2*. Brief summary on wavelets and a key resource bibliography.

#403 PAK251.EXE

Utility to unPAK an IBM ".PAK" file, such as #365 WAVELET.PAK

#390 HACK50.TXT & #391 HACKFG50.PS

Reprint of *Hardware Hacker #50* from *Radio-Electronics*. Wavelets update, including new book, IEEE-SP tutorial, Aware application notes.

#373 HACK49.TXT & #374 HACKFG49.PS

Reprint of *Hardware Hacker #49* from *Radio-Electronics*. Mentions *Wavelets and their Applications* book and *Ultrawave Explorer* software from *Aware*.

#365 WAVELET.PAK

Complete and ready-to-run IBM Wavelet Packet Lab shareware. This is a .PAK compressed file that needs file #403 or its equivalent for unpacking.

#313 GURU73.TXT & #314 GURUFG73.GPS

Reprint of *Ask the Guru #73* that discusses three video compression schemes. These include wavelets, DCT/JPEG, and fractal compression methods.

#258 HACK42.TXT & #259 HACKFG42.PS

Reprint of *Hardware Hacker #42* from *Radio-Electronics*. Fundamentals of transforms, along with examples of wavelet video compression.

#195 HACK38.TXT & #197 HACKFG38.GPS

Reprint of *Hardware Hacker #38* from *Radio-Electronics*. A first introduction to wavelets and wavelet theory. Includes 13 entry sampler bibliography that shows the wide extent of wavelet aps.

Fig. 3 – WAVELET TUTORIALS AND SHAREWARE available on GEnie PSRT. You can call (800) 638-9636 for your voice connect info.

rough reading by mere mortals.

A brief story on optical wavelet uses appears in the August 1992 issue of *Photonics Spectra*. All those optics folks sure do have it easy. They just dump a pile of crockery on the table, squirt some light through it, and they get instant real time 2-dimensional *Fourier* or wavelet transforms. None of the old point-by-point computation nonsense for them.

An entire issue on optical wavelet transforms appears as the September 1992 issue of *Optical Engineering*. I have added #494 EMERGOP2.PS and #456 WAVELETS.PS to *GEnie* PSRT to go along with all the rest of our wavelet downloads. A complete list appears in figure three.

Multilayer PC Breakthrough– I am still looking for a hacker solution that makes printed circuit plate-through holes cheaply possible at home. Or some workaround which flat out does away with the need for plate-thru.

A major step in this direction has been taken by *Sheldahl*. Whose new special adhesive lets you build ultra expensive multilayer boards out of the cheaper double sided ones. Sadly, you still need some plate-through.

Their *Zlink 1900* is basically a new adhesive which conducts only in its thickness direction. Just take a pair of double sided boards and selectively apply this adhesive to one of them. You then add heat and pressure to bond the pair together. You can end up with either a three layer or a four layer board at a tiny fraction of the going price. And, yes, you can do six layer, eight layer, as many as you want. Even have buried plate through holes! Far simpler, cheaper, and with a much lower scrap rate than before.

Carefully isolated solder particles make the adhesive conduct in only one direction. Their conductivity is about the same as real multilayer.

A small free sample is available from Sheldahl on request.

Buckyballs– The price of Buckyballs continues to drop dramatically, and these are now hacker affordable. The leading supplier remains *MER Inc.* and their pricing starts as low as $5.50 a gram raw, and $90 per gram fully refined. Minimum order is $50.

Meanwhile, a *fourth* carbon form has been discovered that is called the *Buckytube*. Hollow cylindrical pipes of carbon that have both the hardness of diamond and the surface area of graphite. Possible new uses include lubricants, and unique materials that conduct heavily in only one direction. Check out the August 17 issue of *E.E. Times* for a summary update.

More on FM antennas

Last month, we checked into the fundamentals of distant FM reception. We have had some requests for still more info, so here goes...

The noise situation at 100 Mhz is a tad further complicated than I first made out. If you do have any remote rural site, then your first stage KTB thermal agitation noise does in fact dominate. And the best noise figure you can get is super important.

Atmospheric noise is negligible at FM frequencies. Galactic noise runs ten decibels or so above KTB around 100 MHz. But you do not normally point a FM antenna straight up on a clear day, so this is also no problem. The potential killer is the man-made noise, which can be 25 decibels above KTB in suburban locations, and 40 decibels or more in urban locations. Nearby dimmers or computers could also induce these noise levels.

Most of the man-made noise comes from car ignitions. It sure would be interesting to watch the FCC try and enforce the same Part 15 rules and regulations on Detroit iron that they do on Hardware Hackers. Talk about potential noise levels! The howl over this would be unbearable.

At any rate, you'll still want to get the best first stage noise figure you can. But it might not help you out too much if your external noise is much stronger than KTB.

On the other hand, a slight increase in antenna gain can make a dramatic improvement in your FM reception.

This happens because of a limiter's *capture effect*. For instance, if you've got a noisy FM signal, an increase of only *two* decibels in antenna gain or S/N ratio can make up to a *seven* or *eight* decibel improvement in receiver

(A) An ordinary dipole has an impedance of a balanced 75 ohms resistive just below its resonance. But any thick conductors or nearby elements lower this resistance or add some unwanted series reactance.

(B) Folding a dipole into a hairpin loop will raise its input impedance by four times. The impedance just below half of a wavelength is a balanced 300 ohms resistive. Careful tuning is needed in the real world.

Fig. 4 – FOLDING A DIPOLE raises its resonant impedance by four times.

quieting.

I've found several interesting FM antennas. The Radio Shack 15-1636 is cheap at $17 and easy to find. And it does a good job in near fringe areas. But it is just plain too small. It only measures four feet by five feet, while a no-compromise Yagi solution will measure five by thirteen.

Radio Shack used the broadband co-linear array, rather than a Yagi design. Then, to save on the materials and size, they apparently designed it up at 120 Megahertz or so and hoped some gain remained down in the FM band. Almost always, a broadband antenna has lower gain than one cut for a single station. From their point of view, this is a useful engineering mix that gives you a small and cheap solution which meets the needs of a majority of their customers.

Their gain is 6.4 DB over a dipole.

Your most rugged "real" FM DX antenna is the *Cushcraft* Y-FM5. This is available by way of *Anixter*, the leading cable TV distributor chain. The gain is 9.5 decibels over a dipole and the cost is around $70. Size is 59 by 104 inches.

Another interesting antenna is the *ChannelMaster* 4408 with a 9 decibel gain in a 138 inch boom length. The price seems high at $104.

The highest gain stock antenna I have found is the *Winegard* CA-6065, that has a whopping 10.6 decibels of gain on a 127 inch boom and costing around $78. This appears to be the best choice.

Be sure to remember that raising your antenna height is usually your surest way to improve your signal to noise ratio in typical locations. The closer to line of sight you can get, the better the results.

But I live in a pecan grove. Nuts. My trees glop over everything, most especially antennas. So some indoor solution seemed better for me.

What about building your own single station FM antenna? In theory, you could pick up another decibel or two of S/N and as much as 8-10 DB of quieting over full band commercial designs. Especially if you are extra careful in tuning and matching. And if you have a high loft in your living room or a wire- and metal-free attic crawl space, an indoor design can be much cheaper than a mast mounted

outdoor one. With fewer hassles. And a Yagi is just a bunch of free floating conductors sitting in magic positions; a wood frame and grommeted screw eyes can be used for support.

First, note that there are two styles of driver elements to a Yagi antenna. As figure four shows us, if you use a half wavelength *dipole* hairpin loop, your terminal impedance should end up near a balanced 300 ohms.

If you use a pair of straight wires of half wavelength total spacing, then your terminal impedance should be a balanced 75 ohms. Note that normal 75 Ohm coax is unbalanced; you will need a baulin or a 1:1 transformer to get from balanced to unbalanced.

Note that driver impedances inside an antenna array usually end up *lower* than these values. They also must be carefully matched for best results.

The bottom line: use a hairpin loop for 300 ohms balanced or the pair of quarter wave wires when you want 75 ohms balanced. Either way, a final

matching will still be needed.

A six element narrowband Yagi cut for 100 Megahertz is shown you in figure five. Use quite *thin* but rigid conductors for your best narrowband gain. Something like *bare* #12 solid copper house wire might be a good choice. To cut this antenna to your desired station, *divide* the frequency in Megahertz by 100 and then *divide* all sizes by the resultant number. For instance, to pick up KDKB at 93.3, all element lengths and all spacings will get divided by 0.933. Note the inverse relationship: stations *under* 100 Mhz need slightly *larger* antenna designs.

The directors should point towards your chosen station. Use a map for starters, and then try rotating a tad either way. Your beamwidth should be around thirty degrees, so pointing just right is super important.

Additional directors can in theory be added, in a size progression. But you only gain something like half a decibel per director, and the size does

All dimensions are shown in decimal inches. The antenna is shown top view, and assumes the station is horizontally polarized.

To cut your antenna for a specific station, divide the station frequency by 100 and then divide all sizes shown below by the same value.

For instance, a 93.3 Mhz station needs all the values divided by 0.933. A 104.5 Mhz station needs all of the values divided by 1.045.

59.56" 55.53" 53.76" 53.02" 53.02" 53.76"

23.52" 29.52" 29.52" 29.52" 29.52"

MATCHING DEVICE

Fig. 5 – AN INDOOR SINGLE-STATION long distance FM antenna can be built using nothing but bare #12 house wire. Here is one possible design. Note that the antenna size should be "cut" for your favorite station. Values shown assume an insulated boom or other supports. All elements must be very straight, rigid, parallel, and precisely centered.

get out of hand real quick like. And a careful match, or finding a local hot spot, or a tad extra height can often get you much more signal.

The theory behind a Yagi antenna? The optimum spacing is usually 0.2 wavelengths. Your driver should be half a wavelength wide. The reflector should be around five percent longer, while your initial director should be five percent shorter. The rest of your directors should progressively be six, seven, eight... percent shorter.

More on Yagi antennas appears in two ARRL publications, the *Antenna Handbook* and *Yagi Antenna Design*. Also see NBS technical note #688.

Close matching of an antenna to its transmission line is essential for the best gain. Your simplest method is called a *gamma* match, and gets done by just spreading the ends of a 300 ohm twinlead to tap maximum signal strength. Better methods appear in the above books.

It would be real interesting to route both of your dipole rods straight into a VHF differential amplifier. Such an *antennafier* can greatly simplify your tuning and matching.

But a lot of black magic could be involved, so be sure to experiment.

Let me know all your experiences with any homemade ultra range FM antenna designs. I'll try to publish the best of them.

New tech lit

A green *1991 Product Handbook* from *MX-Comm*. This little known semiconductor house offers all sorts of exciting hacker chips. Especially those involved with tone signalling, speech scrambling, cellular phones, and pagers. One real sleeper: Their MX009 octal digital gain controlled amplifier array. Lots of ap-notes are also included.

Free engineering samples of their new 41VHS-1 humidity sensor have been offered on professional request from *Victory Engineering.*

Heartland America is yet another Distressed Yuppy Surplus direct mail outfit. They have all varieties of high tech goodies. Their latest new catalog does offer the first laser pointers that I have seen for under $100.

RePlay and *Play Meter* are the two leading trade journals for the coin operated video game industry. While these mostly center on the buying and selling of games and supply products, there are occasional technical articles plus repair books and videos.

If you are interested in starting up your own tech venture, be certain to check into my at long last available *Incredible Secret Money Machine II.* We are also newly shipping the latest *Hardware Hacker III* reprints with their newest updates. See my nearby *Synergetics* ad for more details.

A reminder here that lots of great technical downloads are available on *GEnie* PSRT.

As usual, we've gathered many of the resources mentioned together into either of the *Names & Numbers* or the *Navicube Resources* sidebars. Do be sure to check these out *before* you use our no-charge tech helpline or call for a free hacker secrets brochure. ❖

Don Lancaster's
Hardware Hacker

High side FET drivers
Drawing semilog plots
Laser printer repair kits
Resonance fundamentals
Far East electronic sources

January, 1993

Afew additional comments on the correlation from back in *Hardware Hacker* #54. Our third autocorrelation mask example obviously should have been an 0010 rather than the typo shown. I've corrected this in our *Hardware Hacker IV* reprints.

I should have stated "Radar range *depends upon* your transmitted pulse energy, rather than *is proportional to*. Doubling the transmitted radar pulse energy typically can only extend your effective range by nineteen percent.

Good classic texts on radar include Merrill Skolnick's *Radar Handbook*, and the hoary old "Rad Lab One" that refuses to die. Otherwise known as *Radar Systems Engineering* by Louis Ridenour. Another very outdated but popular intro is Robert Page's *Origin of Radar* from Doubleday.

While much of the information on chirp radar techniques is classified or otherwise hard to locate, the *Theory and Design of Chirp Radars* in the *Bell System Technical Journal* for July of 1960 is a good intro. I've also got a summary in my January 1965 *Electronics World* chirp story. More current info can be found through the *Dialog Information Service*.

Numerous readers have questioned that unusual synchronous rectifer example circuit. Yes, this is correct as shown. And, yes, there is one big hidden gotcha. When a MOS power transistor gets used for a synchronous rectifier, you will run it in its *third* quadrant. Not the first quadrant like you might initially expect. This gets done to keep the substrate diode from shorting out the works.

More on quadrants below.

Additional details on synchronous rectifiers do appear in that *MosPower Applications Handbook* by *Siliconix* and in those *Motion*, *Motion Control*, *PCIM*, or *PowerTechniques* mags.

Fundamentals of resonance

Resonance is certainly one of the most interesting and most important of electronic concepts. But there sure seems to be lots of helpline confusion over what resonance can and cannot do. Yes, you can produce incredible energy buildups in certain resonant circuits. Destructive and even lethal ones. Yes, you can extract this energy if you want. No, none of the stored resonant energy is "free". Just as in a piggy bank, you can not take more quarters out than were put in.

At least I do not know how to do
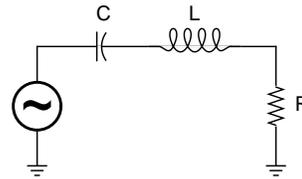
The **RESONANCE FREQUENCY** occurs whenever both the inductive and capacitive reactances are equal...

$$f_o = \frac{1}{2\pi \sqrt{LC}}$$

The **AMPLITIUDE RESPONSE** defines the ratio of the input to the output voltage, expressed in decibels...

$$\frac{e_{out}}{e_{in}} = -20 \, Log_{10} \sqrt{1 + Q^2 \left[\frac{f^2 - f_o}{f} \right]^2}$$

The **Q** or **QUALITY FACTOR** is defined in several different ways, each of which leads to a different application...

(A) As the reactance to resistance ratio...

$$Q = \frac{2\pi f_o L}{R}$$

(B) As the half power bandwidth...

$$Q = \frac{f_o}{f_h - f_l}$$

(C) As the inverse of the damping...

$$Q = \frac{1}{d}$$

(D) As the resonant voltage rise...

$$Q = \frac{(\text{resonant voltage across L or C})}{(\text{resonant voltage across R})}$$

(E) As the ringing rundown time...

A resonant circuit decays to $1/\varepsilon$ amplitude (or 37% = -8.7 decibels) in Q/π cycles.

(F) As the stored energy ratio...

$$Q = \frac{2\pi(\text{energy stored per cycle})}{(\text{energy dissipated per cycle})}$$

Fig. 1 – A RLC SERIES RESONANT CIRCUIT forms the basis for various electronic tuning, filtering, voltage step up, and energy storage circuits. But there is no way I know that it can produce any "free" energy.
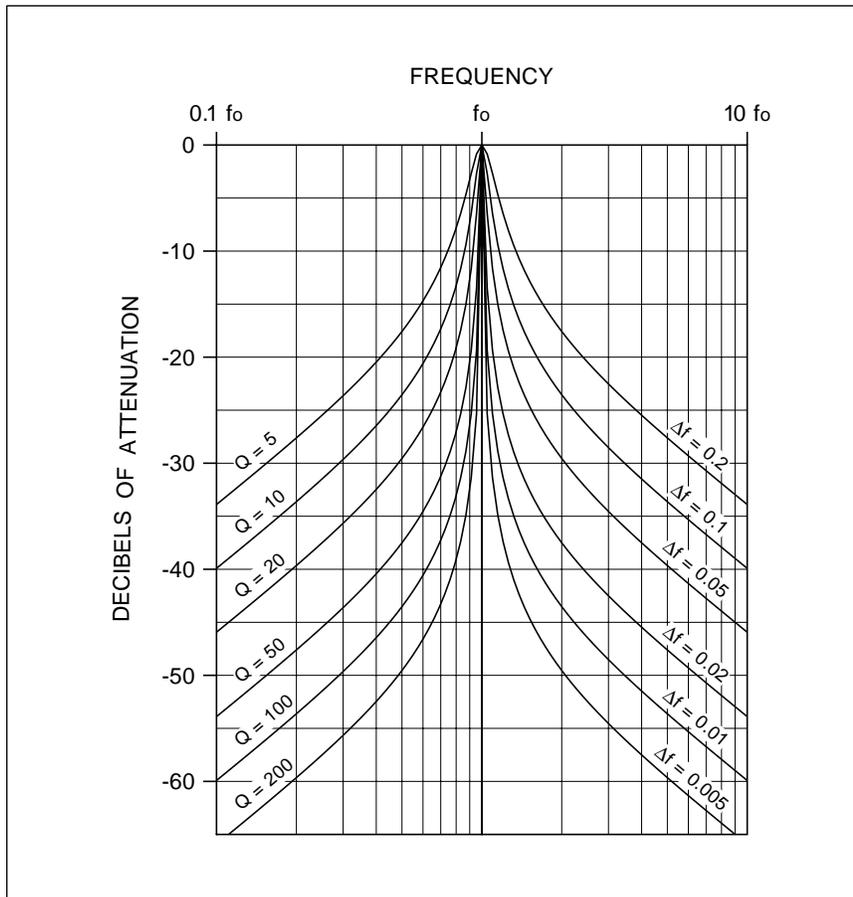
Fig. 2 – EXTENDED RESONANCE RESPONSE CURVES for a series RLC circuit. Note the "flattening out" for frequencies well away from resonance.

this, and 100% of all earlier attempts at "free" resonant energy have failed miserably. Most of these were not even wrong. Let's take a fresh look at resonance fundamentals…

Figure one shows you the simple series combination of one resistor, an inductor, and a capacitor. This is a *series resonant circuit*. Assume for now that the resistance is your load, the inductor and capacitor are very high quality, and the signal source is a very low impedance.

At extremely low frequencies, the inductor will look like a short circuit and the capacitor will appear as a very high capacitive reactance. Very little signal will reach the load.

Similarly, at very high frequencies, the capacitor will look like a short circuit, and the inductor will appear as a rather high inductive reactance. And once again, very little signal will reach the output load resistor.

At one certain frequency, though,

both of the inductive and capacitive reactances will be equal in strength and opposite in sign, *and will cancel out to zero*, transferring *all* of your input signal to the output load. This "magic" frequency is defined as the *resonance frequency*.

As figure one does show us, the resonance frequency is determined by the *product* of your L and C values. Resonant circuits are often *frequency selective*. They allow you to *tune* to a chosen frequency. This is how you select any particular am or fm radio station while you tune out all of the others. Resonant circuits can also store surprisingly large quantities of energy. One very important energy storage use for resonant circuits is in the deflection circuitry of television sets and computer monitors. Sneaky resonant switching tricks are used to sweep the beam back and forth while recycling the available energy.

The "Q" of a series resonant circuit

can get defined in several stunningly unique ways. Q (standing for *quality*) could get defined as the ratio of the resonant inductive reactance to the load resistance. Or as the *bandwidth* between your -3 decibel *half power points*. Or as a function of the *ringing decay time*. Or as the amount of the resonant voltage *increase* you'll get across your inductor or capacitor. Or as determining the ratio of the stored to the dissipated energy per cycle.

All of these figure one definitions of Q are identical, but they will lead you to profoundly different uses and applications for resonant circuits.

You change the resonant frequency by shifting your *LC product*. You can change the Q by shifting the *LC ratio*.

Figure two shows exactly how the response of series resonant circuits will change with frequency and Q. The higher the Q, the *narrower* the final bandwidth between your half power (or 0.707 voltage amplitude) points. Note that each of these curves starts out by rising at +6 decibels per octave, swings up through a sharp resonance peak, and then eventually ends up falling at a -6 decibels per octave rate. No matter how steep your near-resonance dropoff, you reach a point where either the inductor's or the capacitor's reactance is too small to make much difference.

If you need more attenuation well away from resonance, you usually are best off adding extra series resonant *poles*, or otherwise cascading.

You can quickly sketch most any resonant curve. You should get zero attenuation at the center frequency, and -3 decibels of attenuation at the half power bandwidth points set by 1/Q. You then locate your resonant frequency point "Q" (converted to decibels) down and sketch a pair of 6 decibel per octave lines on downward from there. Then smoothly connect all of the dots and the lines.

In high Q series resonant circuits, the usual reactive voltage across the inductor or capacitor will be many times that of the input. For instance, a one volt input at resonance and a Q of 100 will produce a nasty 100 volts across the capacitor or the inductor. Some switching mode power supplies make use of this resonant rise for a transformer-free voltage increase.

The resonant voltage step up can

easily become destructive if the input signal gets too big.

Just as a pendulum swaps kinetic for potential energy as it oscillates, the inductor stored $Li^2/2$ energy is at a maximum on current peaks, and the capacitor stored $Cv^2/2$ energy is at a maximum on voltage peaks. While the energy appears to swap back and forth between inductor and capacitor, *your total stored energy over any one cycle remains constant.*

One definition of Q is 2π times the energy stored per cycle divided by the energy dissipated per cycle. Thus, if you do have a Q of 100, a one amp input and a one ohm load, at series resonance you will dissipate one watt per cycle while you store around 15.9 watts per cycle.

Just where did the 15.9 watts come from? The same place the stash in the piggy bank came from. It got built up earlier, a quarter at a time. During the *transient* times when you first apply a signal, input energy slowly will get saved, building up the inductor's and capacitor's energy storage.

Very large amounts of energy can be stored in resonant circuits. In the case of a large color tv or computer monitor, as much as 5 kilowatts of resonant power are involved in the horizontal sweep circuitry. In a very efficient circuit which continuously recycles resonant deflection currents. More on this in the *Hardware Hacker III* reprints.

If you deliver an impulse to a high Q resonant circuit, it will *ring* for a *rundown* time as shown in figure one. The higher your Q, the longer your ringing time. One obvious use is for electronic chimes and gongs.

More on rundown times appears in my *Active Filter Cookbook.*

Although I have shown a single resistor in our resonant circuit, you really have a load resistor, a source impedance resistor, and the resistive losses in the inductor. All of these have to be accounted for in the real world. For a series resonant circuit to operate, you *must* drive it from a very low impedance source.

You can also create the *dual* of this RLC circuit by placing everything in parallel, creating a *parallel resonant circuit.* Any parallel resonant circuit reaches a very *high* impedance at its resonance and operates only when it

is driven from a very *high* impedance current source. Instead of voltages multiplying by Q, the reactive current multiplies by Q instead.

More on resonance fundamentals appears in most electrical engineering texts. Such as Skilling's *Electrical Engineering Circuits*. And lots more on working with and using resonant circuits appears in my *Active Filter Cookbook.*

PostScript to the rescue

At one time, drawing camera-ready charts and graphs such as figure two was a real hassle. First you had to find some semi-log paper and then trace it to the correct resolution. Then you had to calculate all of the needed points. Finally, you had to ink them with splines or French curves, messy pens, and similar drafting tools. Final size and detail changes were a real bear. Especially if you had to stretch or shrink it in one direction only.

Even then, the editor might decide it's not good enough and has to redo the entire figure from scratch.

These days, instead, you simply use that incredibly superb PostScript language to draw the whole job for you. Instantly and hassle free.

PostScript is one totally *general purpose* and super friendly computer language that is absolutely ideal for many hardware hacking tasks. One of PostScript's utterly minor and almost insignificant capabilities is to dirty up otherwise clean sheets of paper.

In any way you like. Totally device independently. So the same old word processor text file you use for your rough proof copy can also now be phototypeset. Interchangeably, on *any* brand of personal computer.

Figure three shows you the ultra simple PostScript code required to create all the fancy semilog decibel resonance plots of figure two. You just shove this through your favorite word processor and then send it to a PostScript printer using a two-way comm setup. Ethernet, AppleTalk, Serial, or Shared SCSII comm will all work just fine.

But *never* use a parallel port with

```
% Requires persistent download of GONZO15.PTL utility from GEnie PSRT.

guru save /snap1 exch def 200 300 10 setgrid % 30 30 showgrid

line1 1 setlinecap 10 0 mt 26 u 0 0 mt 26 pu 20 pr 26 pd 20 pl gsave line1 stroke grestore
gsave clip newpath 0 setlinewidth  0 setgray

1 1 10 {log 10 mul 0 moveto 0 28 rlineto stroke} for 10 10 100 {log 10 mul 0 moveto 0 28 rlineto
stroke} for 0 2 28 {0 exch moveto 20 0 rlineto stroke} for

/fnc {dup dup mul 1 sub exch div dup mul Q dup mul mul 1 add sqrt log 20 mul neg} def

/vsf {2.5 div 26 add} def /hsf {log 10 mul 10 add} def /incperdec 200 def /startat 0.1 def

/wholecurve{/Q exch def newpath /val startat def val dup fnc mt incperdec 2 mul 1 add {val fnc
val hsf exch vsf lineto /val val 10 1 incperdec div exp mul def} repeat 0.06 setlinewidth stroke}
def

[5 10 20 50 100 200] {wholecurve} forall grestore

/cstretch 0.01 def /sstretch 0.03 def /yinc 1 def

/font1 /Helvetica 0.85 gonzofont
/font2 /Helvetica-Bold 0.85 gonzofont
/font3 /Helvetica 0.7 gonzofont
/font4 /Symbol 0.75 gonzofont
/font5 /Helvetica [0.7 0 0 0.7 0 -.2] gonzofont
/font6 /Helvetica [0 0.85 -0.85 0 0 0] gonzofont

/b+ {gsave newpath /msg exch def translate 40 rotate 1 setlinecap white 0.8 setlinewidth font3
0 .3 mt msg stringwidth pop 0 add r black 0 0.1 msg cl grestore} def

/b- {gsave newpath /msg exch def translate -40 rotate 1 setlinecap white 0.8 setlinewidth font3
0 .3 mt msg stringwidth pop -1 add l black 0 0.1 msg cr grestore} def /kern 0.1 def

font1 10 28.3 (FREQUENCY) cc -3.3 8 (|6DECIBELS OF  ATTENUATION) cl

[{line1 0 26 mt 0.5 u} 10 3] xrpt [{line1 0 2 mt 0.5 l} 4 7] yrpt

0 26.9 (0.|k1 f|5o) cc 10 26.9 (f|5o) cc 20 26.9 (1|k0 f|5o) cc 1 13.6 (Q = 5) b+ 1 11.2 (Q = 10)
b+ 1 8.8 (Q = 20) b+ 19 13.6 (|4D|3f = 0.2) b- 19 11.2 (|4D|3f = 0.1) b- 19  8.8 (|4D|3f = 0.05) b-
19 5.6 (|4D|3f = 0.02) b- 19 3.2 (|4D|3f = 0.01) b- 19 0.8 (|4D|3f = 0.005) b- 1 5.6 (Q = 50) b+ 1
3.2 (Q = 100) b+ 1 0.8 (Q = 200) b+

font1 -.8 25.7 (0) cr -.8 21.7 (-10) cr -.8 17.7 (-20) cr -.8 13.7 (-30) cr -.8  9.7 (-40) cr -.8  5.7
(-50) cr -.8  1.7 (-60) cr

snap1 restore showpage quit
```

Fig. 3 – GURU GONZO POSTSCRIPT CODE used to create camera-ready semilog artwork for figure two. Only your favorite word processor is needed!

PostScript! To do so blindfolds you and ties both of your feet together. Many PostScript programs will not run at all over a parallel port.

All you need to write PostScript code is your favorite editor or word processor.

I have just posted a PostScript for Hardware Hackers tutorial as #511 NUTS9.PS to my *GEnie* PSRT.

Among the many hundreds of other PostScript-as-language files, the full Smith Chart drawing routines as file #367 SMITHCHT.PS and my printed circuits as #401 PRINCRCT.GPS. The PostScript startup secrets tutorial now appears as #335 SECRTEMP.GPS and PostScript speedup secrets tutorial as #460 SPEEDUP.PS. Unique PostScript code to let you instantly draw all the camera-ready figures in this column appears as HACK59.GPS.

Finally, if you do not now have a PostScript printer, I've posted the GHOSTSCRIPT files to PSRT. These let you run PostScript with just about *any* printer. They also give you full viewable display PostScript on any monitor. The current PSRT banner will show you the latest GhostScript version numbers to use.

While figure two can easily be done in "raw" PostScript, I've made my coding even faster and simpler by opening a convenient and powerful layout/illustration dictionary I use.

This file is #517 GONZO15.PTL and gets persistently downloaded at the start of your work session. One single "guru" command opens up this set of power tools for you.

You can also write or call me for a free new PostScript secret resources mailer.

High side drivers

There's a new game in town called *high side drivers* that are becoming super important. A high side driver is a solid state relay placed between the positive dc supply line and any loads that you wish to control.

Automotive people like high side drivers because only a single wire is needed for each load with the chassis forming the ground return. Laptop and palmtop computer folks like high side drivers because the inputs and outputs of the controlling circuits are not hurt by any floating grounds.

Many high side drivers are smart enough to protect themselves against shorts, overloads, and other faults. What gets tricky fast about high side drivers is that the preferred choice in any electronic switch today is the N-channel power MOSFET. To turn on an N-channel MOSFET that's been connected to your positive supply voltage, you'll need a gate control signal well *above* that of the supply.

Before we see just how we can get

a control signal that is well above that of the most positive supply line, let's briefly review just what an N-channel MOSFET is and how it works. Figure four shows details.

You start with a block of P-doped silicon. Add a non-rectifying or an *ohmic* terminal to it, known as the *substrate*. Now you implant two N-channel wells in the substrate. Ohmic contact these and call them the *source* on the bottom and the *drain* on top. Now, build a capacitor by adding a superthin dielectric and a conductor between source and drain. Call this lead the *gate*.

If the gate is at a zero or negative potential with respect to the source, there will be a zero drain to source current, since the MOSFET looks like a pair of back-to-back diodes. There will also *never* be any steady state gate current, since all your gate ever does is charge up or discharge a small capacitor.

Let the gate get somewhat positive with respect to the drain. Electrons have to pile up on the substrate side of the gate capacitor, so that area will become *less* of a P-type material. Let the gate voltage exceed a *threshold* value, and the extra electrons on the substrate side will actually change the substrate into a continuous N *channel* between source and drain. You now have three N regions tied together into a solid block. These look like a plain old resistor and allow current between source and drain.

Below the threshold voltage, you'll have an open circuit between source and drain. Above threshold, you have a small resistor between source and drain. A grounded gate turns you *off*. A gate above the threshold voltage turns you *on*. The typical threshold is around +4 volts or so, but to really turn the device solidly on, a gate to source voltage of +10 is preferred.

Unlike the NPN power transistors, there are no saturation effects or P-N junctions in your main current path. There is also zero steady state gate current needed. A turned on MOSFET acts as a plain old low value resistor.

Your "on" resistance of a single N-channel MOSFET isn't really that great. For instance, in the CMOS 4066 quad analog switch, the on resistance is a high 16 ohms or so. To beat this, power MOSFETS are really hundreds,

drain	drain
N	N
gate — P substrate	gate — P substrate
N	N
source	source
Zero or low gate voltage lets P substrate remain that way, blocks source to drain current.	Positive gate voltage builds up electrons, forms a continuous N-channel, and turns on.
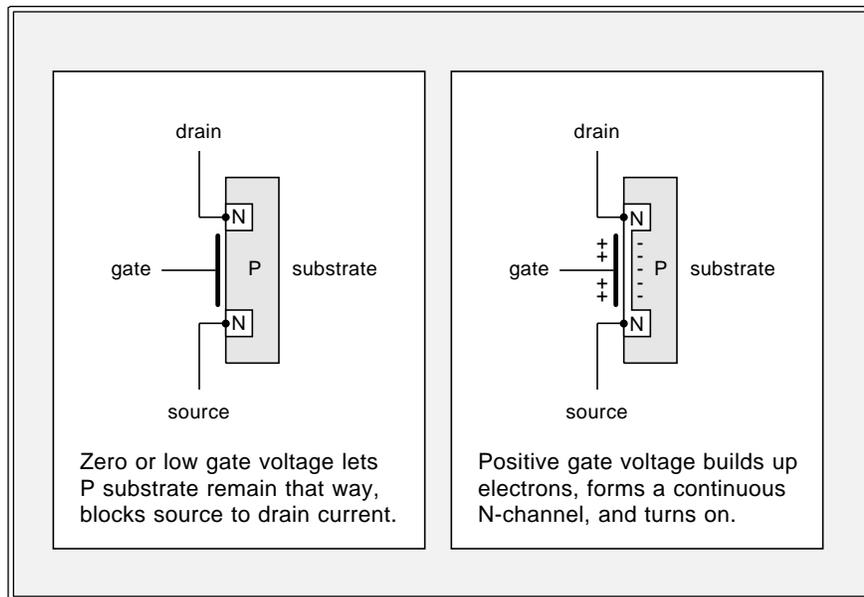
Fig. 4 – THE N-CHANNEL POWER MOSFET is now the most popular and most economical power switch in use today. Increasing the gate voltage above its threshold value turns the device on.

or even thousands of tiny MOSFET transistors all internally connected in parallel.

There are lots of sources of power MOSFET chips. *Motorola*, *Siliconix*, *Texas Instruments* and *International Rectifier* are typical. Because of their quite low cost and high gain, these have become the main power switch of choice for many electronic uses. Although there are also P-channel MOSFETs, they do cost more and are less efficient. And because of certain fundamental device physics, they are likely to remain so.

Since a turned on power MOSFET is really nothing but a resistor, *it does not matter which direction the main current goes*. If you do the obvious and make the drain go positive with respect to the source, you are said to be in *quadrant I*. On the other hand, if you make the drain negative with respect to the source, you end up in *quadrant III*. High side drivers work in quadrant I. But most synchronous rectifiers which use MOSFETS will normally run in quadrant III to avoid substrate diode conduction.

To use a N-channel MOSFET as a high side driver, you just connect the drain to the positive supply, and your source to the load being controlled. To turn the switch off, you leave the gate at or below the positive supply voltage. To turn the switch on, you connect the gate to a value well *above* that of your positive supply, typically by +10 volts or so.

Where on earth do you get an extra supply that is well above your main supply voltage? Quite little average current is needed since you are only charging or discharging a small gate capacitor. A number of new low cost integrated circuits are now available which use *charge pumps* and similar circuit tricks to let you reliably apply N-channel MOSFETS for high side power switches. Typical examples do include that *International Rectifier* IR2125, the *Maxim* MAX620, and the *Linear Technology* LTC1155.

The LTC1155 is a very interesting chip. This gives you a self-protecting pair of micropower dual high side drivers in a single eight pin mini-DIP. A dual high side circuit breaker is shown you in figure five.

Here is how either half of this circuit works: A built-in charge pump continuously generates a reference voltage above the postive supply.

Leaving IN1 low leaves your load unpowered. Raising IN1 to a TTL logic one (+2 volts or higher) turns on your load. The load gets turned on by supplying the boosted gate voltage to the power MOSFET. With a five volt supply, your boosted voltage is around +12 total, or around +7 above the supply. Higher boost voltages are generated for higher value supplies.

The load power normally stays on until IN1 drops to a logical zero under 0.8 volts. There's also a protection input known as DS1. If DS1 ever gets more than one tenth of a volt below the supply, it automatically shuts things down. You can add a load sensing resistor of one tenth of a volt per amp to shut down on any overcurrent as shown.

Some loads might have large but expected inrush currents. This often happens with incandescent lamps and solenoids. A resistor and capacitor time delay can be added to the current sensing to allow inrush currents but still react to overloads. This simulates the operation of a slow blow fuse. See the LTC1155 data sheet for more details. Many other innovative circuit examples are included.

Be certain that your inrush filter capacitor goes to the positive supply and *not* to ground!

A snap action gets involved on a circuit overload. Once any overload occurs, the input must be brought low and then back high again to repower. This can be done either manually or automatically.

Switching times are fast but not stunning. The turn-on time is around half a millisecond. The usual turn-off time is around 32 microseconds.

Note that any simple *exclusive-OR* gate could get used for external fault detection. If the on command is high and your load is low, you have an output short. If the on command is low and the load is high, you have an output open. If both are low, you have a normal switch turn-off, and if both are high, you'll have a normal switch turn-on condition.

The standby current when off is a mere 8 microamps, making this ideal for battery saving applications.

Lots of additional details on analog switches are in my *CMOS Cookbook*.

You'll be seeing lots more on high side drivers as they are one of the hottest of new electronic applications areas. What unusual or off-the-wall uses for these can you think of?
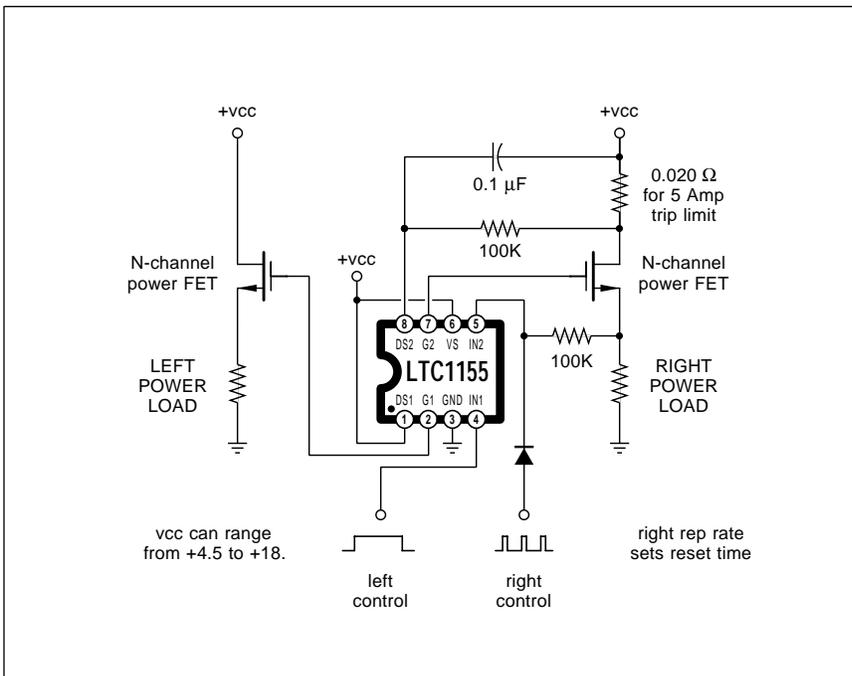
Fig. 5 – A DUAL HIGH SIDE DRIVER. The left side is shown as a simple power relay, while the right side includes "slow blow" current sensing and an auto breaker reset. The boosted gate voltages are internally generated.

SEMICONDUCTOR RESOURCES II

Gould AMI
2300 Buckskin Road
Pocatello, ID 83201
(800) 538-7736

Harris Semiconductor
2401 Palm Bay Road
Palm Bay, FL 32905
(305) 724-3739

Hewlett-Packard
PO Box 10301
Palo Alto, CA 94303
(415) 857-1501

Hitachi
2000 Sierra Point Pkwy
Brisbane, CA 94005
(415) 589-8300

Hughes Aircraft
500 Superior Ave M/S B1250
Newport Beach, CA 92658
(714) 759-2727

Hyundai
166 Baypointe Parkway
San Jose, CA 95134
(408) 473-9200

Intech
67 Alexander Drive
Research Triangle, NC 27709
(919) 549-8411

Integrated Circuit Systems
PO Box 968
Valley Forge, PA 19482
(215) 666-1900

Intel
1000 Business Center Dr
Mt. Prospect, IL 60056
(800) 548-4725

Internat'l Microcircuits
525 Los Coches Street
Milpitas, CA 95035
(408) 263-6300

Internat'l Micro Electronics
PO Box 170415
Arlington, TX 76003
(817) 561-2244

Lambda
121 International Blvd.
Corpus Christi, TX 78406
(512) 289-0403

Lattice Semiconductor
5555 NE Moore Court
Mt. Prospect, IL 60056
(800) FAST-GAL

Linear Technology
1630 McCarthy Blvd.
Milpitas, CA 95035
(408) 432-1900

LSI/CSI
1235 Walt Whitman Road
Melville, NY 11747
(516) 271-0400

LSI Logic
1551 McCarthy Blvd.
Milpitas, CA 95035
(408) 433-8000

Maxim Integrated Products
120 San Gabriel Drive
Sunnyvale, CA 94086
(408) 737-7600

Micrel Semiconductor
560 Oakmead Parkway
Sunnyvale, CA 94086
(408) 245-2500

Microchip Technology
2355 W. Chandler Blvd.
Chandler, AZ 85224
(602) 963-7373

Micro Linear
2092 Concourse Drive
San Jose, CA 95131
(408) 433-5200

Micron Technology
2805 East Columbia Road
Boise, ID 83706
(208) 386-3900

Micro Power Systems
3100 Alfred Street
Santa Clara, CA 95054
(408) 727-5350

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

Mitel
2321 Morena Blvd Ste M
San Diego, CA 92110
(619) 276-3421

Mitsubishi
1050 East Arques Avenue
Sunnyvale, CA 94086
(408) 730-5900

Motorola
PO Box 1466
Austin, TX 78767
(800) 521-6274

MX-Com
4800 Bethania Station Rd
Winston-Salem, NC 27105
(800) 638-5577

National Semiconductor
47 Ellis Street
Mountain View, CA 94043
(800) 632-3531

NCR Microelectronic
3718 North Rock Road
Wichita, KS 67226
(800) 325-SCSI

NEC Electronics
PO Box 7241
Mountain View, CA 94039
(800) 632-3531

More semiconductor houses

This month, we will continue our multi-part resource sidebar listing of semiconductor houses, picking up *Gould* through *NEC*. I have left off some of the more obscure outfits that don't seem too innovative.

General Electric, *Intersil*, and *RCA* are now part of *Harris*. A few of their better chips remain available.

Similarly, the *Sprague* folks have now become *Allegro*, *Amperex* has sold out to *Philips*, and the dregs of *Mostek* were long ago absorbed into *SGS*. *General Instruments* has moved across the country and all their good sound effects chips fell off the truck on the way. Most of the low volume power semiconductor houses are now changing their names so fast it is hard to keep up. See *PCIM* and similar trade journals to find just out who is currently calling themselves what in this specialty area.

Laser repair training bargain

Canon Inc. manufactures by far the most popular laser printer engines in use today. *Hewlett-Packard*, *Apple*, *QMS* and several of the other major players all use Canon engines in their laser printers.

Of these printers, by far the most popular mid-range units all will use the Canon SX engine. And by far the largest single repair item on all these machines is cleaning and repair of the SX fusion assemblies. The stuff that typically goes wrong with SX fusion assemblies are the scored or swollen rollers, broken or burned out quartz heater lamps, worn or tooth-missing gears, dirty or defective temperature sensors, feed creasing and jamming, or general grunge accumulation.

Don Thompson of *TechniGraphics* has long offered the very finest laser printer repair training. He recently sent me a sample of his new *SX Fuser Assembly Master Kit*, and has agreed to offer it to *Electronics Now* readers at a very special price $350.

For the price of one new fusion assembly or one single fusion repair from a typical computer dealer, you get a complete set of *all* the quality hand tools and supplies required to become a fusion rebuilding expert; a two hour lucidly detailed videotape; secret insider info on the "tye wrap"

spring retainer method; a personal tech help hotline; and replacement parts for just about everything that can go wrong with these units.

Individual bits and pieces are also economically available as needed to continue your own fusion rebuilding enterprise. Most other sources will sell only complete assemblies.

Rebuilding kits for other printers and most other fuser assemblies are being offered.

Far East sources

I continually get helpline calls for hardware hackers who seek Far East contacts for computers and electronic assemblies and custom work. We have already seen that *Trade Winners* is one possible resource. This is sort of a Hong Kong *Computer Shopper*, only wholesale.

But I may have found the mother lode. There's now a Hong Kong trade journal publisher by the name of *Asian Sources* who publish seven magazines, one each for computers, electronics, electronic components, timepieces, fashion accessories, home products, and "hardwares". The latter is apparently their term for machinery and industrial supplies. Yes, they are all printed in English.

These cost $70 each per year via surface mail. But they do offer free samples on a one-sample-per-request basis. Per their bingo cards.

New tech lit

From *Dallas Semiconductor*, a fat new 1993 Product Data Book. Full of exciting, innovative, and very useful hacker chips. Mostly timers, clocks, non-volatile memory, smart sockets, telephone and security stuff.

Through *Cherry Semiconductor*, a new data book on automotive, sensor, motor controlling, and power supply circuits. And from *Reticon*, a *Solid State Camera Products* data book.

The *Industrial Marketplace* is a great tabloid shopper with lots of outstanding surplus offerings and full auction listings. Mostly mechanical and machine shop stuff, but definitely some electronics. I get the impression that this is *the* wholesaler's surplus insider's mag.

Another interesting and readable surplus shopper mag is the *ASD/AMD TradeNews*. But it does not strongly

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NAMES AND NUMBERS

ASD/AMD Trade News
2525 Ocean Park Blvd
Santa Monica, CA 90405
(800) 421-4511

Asian Sources/Wordright
1020 Church Street
Evanston, IL 60201
(708) 475-1900

Bell System Tech Journal
101 John F. Kennedy Parkway
Short Hills, NJ 07078
(201) 564-4454

Cherry Semiconductor
2000 S County Trail
East Greenwich, RI 02818
(401) 885-3600

Dallas Semiconductor
4401 S Beltwood Pkwy
Dallas, TX 75244
(214) 450-0448

Dialog
3460 Hillview Avenue
Palo Alto, CA 94304
(415) 858-2700

EG&G Reticon
345 Potrero Avenue
Sunnyvale, CA 94086
(408) 245-2060

Garden Fresh Replicas
PO Box 208
Neosho, MO 64850
(800) 545-7304

GEnie
401 N Washington Street
Rockville, MD 20850
(800) 638-9636

Hewlett-Packard
PO Box 10301
Palo Alto, CA 94303
(800) 752-0900

Industrial Market Place
7842 N Lincoln Avenue
Skokie, IL 60077
(800) 323-1818

International Rectifier
233 Kansas Street
El Segundo, CA 90245
(310) 322-3331

Linear Technology
1630 McCarthy Blvd
Milpitas, CA 95035
(408) 432-1900

Maxim
120 San Gabriel Drive
Sunnyvale, CA 94086
(408) 737-7600

Motorola
5005 E McDowell Road
Phoenix, AZ 85008
(800) 521-6274

Siliconix
PO Box 54951
Santa Clara, CA 95056
(408) 988-8000

Speleonics
Box 5283
Bloomington, IN 47407
(812) 339-7305

Texas Instruments
PO Box 809066
Dallas, TX 75380
(800) 336-5236

Don Thompson
23072 Lake Center Dr #100
El Toro, CA 92630
(714) 855-3838

Trade Winners
PO Box 2868
Vancouver, WA 98668
(206) 694-1765

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emphasize electronics.

Replica kale is newly offered by *Garden Fresh Replicas.*

Free samples of their new AlInGaP lamps are available through *Hewlett Packard.* These are incredibly bright LED's visible in direct sunlight. And intended for eventual use as auto tail lights and turn signals. These are the first LED products with efficiencies about the same as an incandescent lamp. A detailed discussion of this new technology appears in the curent issue of *Speleonics.*

I've recently posted a thorough and complete list of inventor's resources to PSRT as #520 INVENORG.PS. Also see #477 NOPATENT.PS. We'll have some more info on inventions and

inventing in a future column. Many other of my PostScript programming examples are also uniquely available in this PSRT library. Your average downloading costs are around twenty one cents.

Sorry for the inexcusable delays, but I've at long last gotten my new *Incredible Secret Money Machine II* backlog worked off. I am currently shipping autographed copies of this newly revised guide to forming your own small scale tech, craft, or artistic venture.

As usual, we've shown most of the mentioned resources in our *Names & Numbers* or *IC Resources* sidebars. Be certain to check here first before calling our tech helpline. ❖

Don Lancaster's
Hardware Hacker

Relaxation oscillators
Newtek's video toaster
Broadcast trade journals
Syncronizing video sources
Electric Discharge Machining

February, 1993

This month, we seem to have a pair of really exciting new opportunities from opposite ends of the broad hardware hacking spectrum. Before we begin, though, our usual reminder that you can pick up technical help, consultant referrals, and off-the-wall networking by calling me per the box below.

Or by accessing our superb *GEnie* PSRT which has just seen its 40,000th library download. You can voice call (800) 638-9636 for connect info.

Let's start off with…

Newtek's Video Toaster

Tim Jenison recently sent me one of his *Newtek* video toasters to play with. What follows is just some of my preliminary impressions and random comments, rather than a thorough or unbiased review…

Their video toaster is basically an Amiga computer having some special software, a plug-in card, and several extra jacks on the back. At a street cost of $2000 (card only) or $4000 to $5300 (a full slow or fast system), the video toaster can replace something like $100,000 worth of real broadcast quality video postproduction editing equipment.

Not imitates. Replaces outright. Or even totally blows away.

In theory, you can now cheaply and quickly produce total broadcast quality videotapes in your own home. The present genlocking and switching abilities of the video toaster do seem three years or so ahead of anything Mac based, and eons beyond anything using an IBM or PC platform.

The video toaster performance is absolutely and totally stunning. But let's knock it anyway. Just so you are sure what you are getting into.

First, if you just want to slap some titles or computer art onto any old home video, that virtually unknown $129 *Apple II Video Overlay card* is much cheaper, surprisingly powerful, and vastly easier to use. *A2 Central* is one continuing source.

Second, you do not simply drop this beast down on your kitchen table.

An *entire room* dedicated *exclusively* to the video toaster is your minimum possible workspace. Although quite compact by itself, the toaster often will attract bulky and expensive high tech goodies like a huge magnet.

Third, plain old VHS is flat out not suitable for *any* serious production or editing. Period. One big reason is the *generation loss* effects where copies simply are not as good as an original. Another is the inability to selectively edit a single frame. Writing a single frame gets essential for any animated sequence. Many of the toaster's more exotic features are definitely not VHS compatible. No way.

Yes, you can handle fairly fancy production with the latest of Super VHS or Hi-8. But if you're in the least serious about creating a commercially marketable product, a minimum of *Sony Betacam* should probably get used for your taping and editing.

Fourth, by the time you pick up a "real" camera or two, a "real" VCR or two, the three quality color monitors required, the two time base correctors demanded for the VCR's, your station synching genlock, an extra ac circuit breaker, your storyboards, and some support furniture, your price for the toaster itself does not seem to matter all that much.

Fifth, the toaster does not address any audio mixing or processing. It simply passes the audio on from input tape to output tape. There's sort of an unbalance here, since the toaster does so much so well on the video tracks.
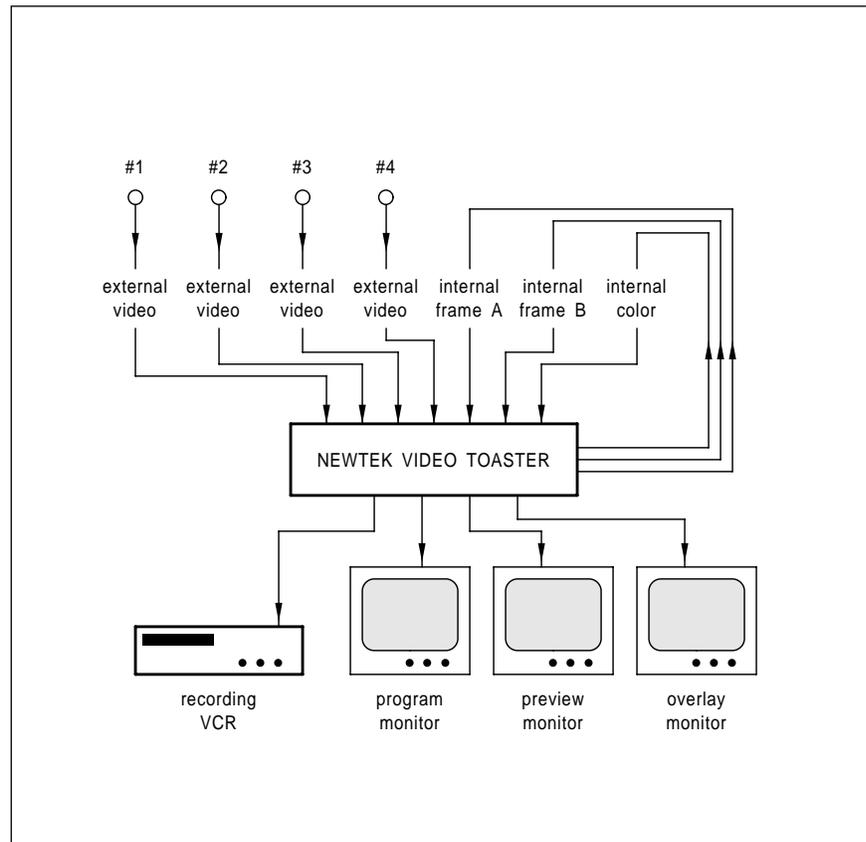
Fig. 1 – NEWTEK'S VIDEO TOASTER 2.0 can be used to cheaply replace as much as $100,000 worth of video editing and post-production equipment, while still offering full network broadcast quality. Best results are obtained with fancier video formats that allow single frame writes.

camera edit
source #1

camera #1 outputs
its station sync
to edit sources
#2, #3, and #4

camera edit
source #4

sync out

sync in

VCR edit
source #2

VCR edit
source #3

• • •

• • •

time base
corrector

time base
corrector

genlock
synchronizer

genlock
synchronizer

Video input sources to Newtek Toaster
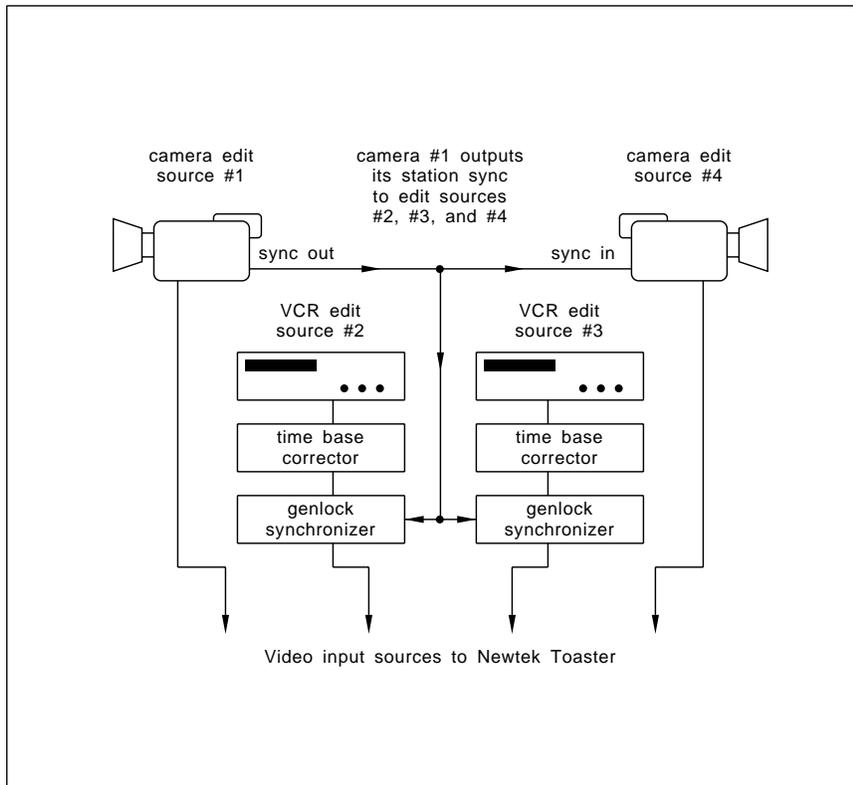
Fig. 2 – AS WITH ANY VIDEO EDITING SETUP, all input VCR's must be time base corrected, and all input video sources must be carefully synchronized together. This arrangement uses Camera #1 for your station sync.

Yet it almost completely ignores the audio side.

Finally, the toaster has a very steep learning curve. Bunches of time and effort are required to do the job right. Just because your toaster *potentially* can do full broadcast quality doesn't mean that you still can't create totally and utterly atrocious results.

So, what is in the box?

Figure one shows a typical toaster configuration. The toaster card and software consists of nine very fancy subsystems. These are the *switcher*, the *keyer*, the *framestore*, the *chroma FX processor*, *digital video effects*, a *character generator*, a *ToasterPaint drawing program*, the *Lightwave 3D* modeling program and the *genlock*.

The production switcher forms the heart of the system. There are three buses, called the *program* bus, which is your *current* output, your *preview* bus, which often will be your *future* output, and the *overlay* bus, which often determines how your preview and future outputs will be combined.

Each bus can get manually or else software connected to seven different sources. These include four live video inputs, two still picture frames, or a background color.

Say you want to switch from live video to a color title screen. To do an instantaneous switching, you would put the live video on the program bus, the title art on the preview bus, and press the *take* button. To do a manual gradual fade, there's a large mouse controlled "T" handle which lets you gradually change between the two. There's also lots of preprogrammed wipes and fades available. Either in manual or 3-speed automatic. Plus you can write your own font software or use third party effects.

It gets complicated from there, but you can easily do picture-in-picture, and pretty much every other special effect that you'll see on a network or cable program. A full animation is certainly possible. But *only* when you use those video formats and control hardware that let you do single frame writes under exact control.

The luminance keyer lets you put live action over a fixed background. As a selected "white" or "black" level gets tripped, your switcher instantly changes between the action and the background. The frame grabber does what you would expect: freezing an instant of live video for future use.

Except that it actually grabs *four* fields at once. This is needed because there are two fields per frame and two frames used for the NTSC color phase sequence. A number of options are available to remove any blurring or motion in any particular field.

The chroma FX processor lets you do all sorts of neat color stuff, while the digital video effects give you lots of wowie-gees like sliding, spinning, zooming, or a spherical mapping. All of which is software programmable. The key to all these effects is to reach into a RAM memory and address it in a nonobvious manner.

The character generator is used to place messages upon your screen. It offers some very fancy special effects including glitter, highlights, chromes, drop shadows, etc…

ToasterPaint is a powerful drawing program, while the Lightwave 3-D is a sophisticated image rendering and animation system. Once again, your actual animation is only useful on the video standards and support hardware that allows single frame writes. Your animation sequences can be up to 120 frames, or four seconds long.

Ah yes, that genlock. When you take any old pair of video sources and try to switch between them, you will get a horrible and useless glitch. The only way around this is to make sure that *each* of your video sources gets carefully locked to the *exact* same timing. By an exact lock, this means that all horizontal lines must start precisely at the same instant and last exactly the same time. Your color phase on all the lines must precisely match. The vertical synchronization pulses must be precisely aligned. And finally, those four NTSC color phase fields must be in precisely the correct time sequence.

Now, *if* you have one *single* live video camera source or one *single* off-the-air live video broadcast, your toaster will automatically lock all of its effects. Genlock here should be no problem. But *any other combination*

of sources needs careful thought as to how your genlocking is done.

Most VCR's introduce a second big problem, even if you are only using one of them. Mechanical differences, alignment changes, and tape stretch might slightly but continuously jitter the timing coming off a prerecorded source. A twenty nanoseconds error is noticeable.

To clean up the output from any recorder, one or two steps might be needed. A *time base corrector* simply eliminates jitter. If you are using *one* recorder as your *only* video source, then a plain old TBC will suffice. On the other hand, if you are using two or more video sources, your recorder output will have to route through a much fancier combination TBC and *frame synchronizer*.

Typical low end TBC's include the *Digital Processing* VT-2000 and the *Iden* TR-7. Fancier TBC/synchronizer devices do include the *Hotronic* AP41 and the *Iden* IVT-7. The typical street pricing ranges from $750 up to $1600. With widely expanding markets, it's likely that these prices should soon drop dramatically.

Grass Valley Group and *Ikegama* offer full broadcast quality switchers, synchronizers and correctors. And so does *Sony*. These are not cheap.

At any rate, if you want to use multiple video sources, you pick your absolute best source and use it for the *station sync*. Additional sources that accept external synchronization can be cable connected to this one station sync source. Sources that cannot be externally synchronized have to go to their own TBC/synchronizers, which in turn are cable connected to your station sync.

Figure two shows you a typical synchronization hookup. Remember that *all* recorders *must* be time base corrected, and that *only one* source is allowed to provide station sync. All other sources must be locked.

One more time: All VCR's need at least time base correction, and all of your video sources *must* get precisely locked together for the toaster or any other video production system.

What's wrong with it?

While the current 2.0 version of the video toaster is a stupendous product, I feel this certainly could be further improved. Firstoff, a true Mac based version is a must. Commodore may have a temporary and illusory lead on genlocking, but the Mac color image generation and editing has long ago passed up the Amiga (and everybody else) like they were sitting on blocks. Obvious examples do include Pixar's *Renderman*, Apple's own *QuickTime* and Adobe's *Photoshop*.

Newtek's new *Mac Desktop Video Gateway* is a good first step towards full Mac compatibility.

Speaking of Adobe, some toaster compatibility with their PostScript language and its *Carousel* offspring sure would be useful. PostScript is ideal for most video artwork, either regular or animated. While the public domain *GhostScript* (now available cheaply on my *Genie* PSRT) could be immediately used, a genuine Adobe Display PostScript is the best choice. PostScript type I and type III fonts are ludicrously better than the current crop of toaster characters.

Full compatibility with Kodak's new *PhotoCD* technology is also a must. As is better audio processing; full support for wavelet, fractal, and the MPEG compression options; and improved time code use.

And their toaster would be even more useful if some other technical improvements can come down. Like figuring out a method to effectively single frame edit plain old VHS. Or

getting true read/write CD ROM out of the starting gate. Or speeding up the CD ROM access by a hundred or more. Probably the best way to do this is with multiple heads and some sort of holographic sensing. Orange or (sigh) blue laser diodes would also help considerably with their shorter wavelengths and higher densities. As would a giant two-port buffer.

The price of time base correctors and synchronizers also has to drop bunches. But this will surely happen as this market expands. We also need a newer *GoVideo* like product having multiple genlocked and single frame writable recorders all in one low cost system package.

Also needed are lots of improved "on the fly" techniques similar to an instant replay. Where a full minute of RAM based video could be instantly synchronized with and then real time overlain to *any* video format.

Who needs it?

Judging by all of the people who immediately piled up on my doorstep on the mere *rumor* I was getting one, pretty near anybody. In fact, your chances are good that "Wanna play with my toaster?" is now the number one singles bar pickup line.

Its amazing who your friends are.

Let's see who was on the pile. Phil runs the alternate cable service here and is about to offer ultra-cheap local

TOOL

DIELECTRIC FLUID
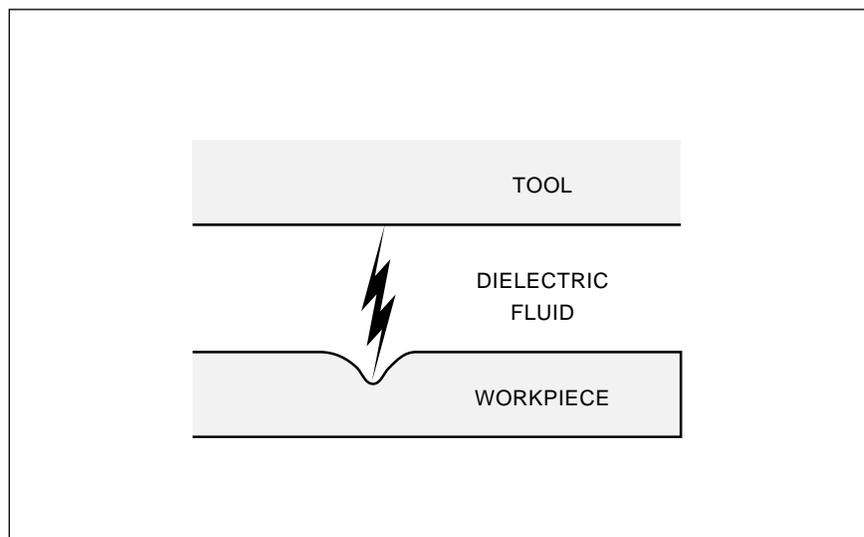
WORKPIECE

Fig. 3 – ELECTRIC DISCHARGE MACHINING uses a spark to literally blast craters out of a workpiece. The dielectric fluid washes the dregs away after each spark. Surprisingly, sub mil accuracies and microinch finishes are easily and cheaply possible. The trick is to use lots of sparks and tiny craters.

ads. Diane is the public information officer (a.k.a. the directorate of the ministry of propaganda) for a federal bureaucracy. Henry now consults for a university multimedia department. Craig is a timber management type. Kathy is big into theater arts. Bee is into how-to papermaking. Irene sells weaving and loom stuff.

Boyd shoots rodeo events. Dan is heavy on his computer servicing. Jeff now publishes a high-tech magazine. And Chris is shooting fire department sprinkler hookup videos. Myra is now busy networking all her regional Bed and Breakfasts. Mike is editing down his UFO stuff. Jay has been making a big flap in avian raptor research. Also birds. Keith is the honcho of a large regional rent-a-vid chain. And I am producing PostScript intro videos.

To get started off with the Newtek video toaster, first get a copy of the mind-blowing free video demo, either by calling them or circling the bingo card. Newtek also has an outstanding tech support helpline. One of many retail toaster sources is *B & H Video*, who also stock TBC cards.

The leading mag is *Video Toaster User*, while *Coffee and Toast* is one interactive video service. One source for toaster fonts is *Kara Computer Graphics*, while public domain disks of toaster effects are available at $6 each from *Timmins/Kingsway*.

Two associates of mine who offer custom video editing work and post production include Limel Schneiker of *HDS Systems* (for Mac based apps) and Boyd Bairn of *Rodeo Video* (for Sony Betacam).

Electric Discharge Machining

EDM, otherwise known as *spark machining* has held a rather obscure corner in the odd world of industrial electronics. But EDM has recently moved out of the toolroom and onto the production floor. There's nothing inherently expensive or complicated about EDM. It has some great new hacker potential. Especially since it lends itself so well to CAD/CAM and computer control.

Figure three shows you the basic idea. You place a *workpiece* of metal to get machined under a normally recirculating and insulating dielectric fluid. While kerosene was originally used, deionized water with a polymer resin is more popular today. You then bring a tool close to *but not touching* your workpiece and then discharge a capacitor between the two.

Which creates a spark.

The spark vaporizes a volume of the dielectric and blasts a crater out of the workpiece, creating a liquid metal puddle. After the spark ends, the puddle solidifies and the moving dielectric washes the dregs away. The "dirty" electrolyte is then filtered and recycled for reuse.

The process is repeated zillions of times. The next arriving spark strikes somewhere else, since the crater just increased the average spacing. As the workpiece erodes, the tool can get lowered somewhat. Eventually, the workpiece should assume the exact shape of the tool. Servo controls can sense the spark intensity and control the descent rate, making sure that an optimum spacing between a tool and workpiece is held.

Although spark machining sounds rather crude, EDM can easily do ultra smooth microinch machining having accuracies to a fraction of a mil.

Figure four shows several popular variations. With *die sinking EDM*, a master pattern is "pushed" into the workpiece. The tool can be arbitrarily complex and virtually any shape so long as there are zero undercuts. *Wire EDM* works sort of like a bandsaw. You start with a supply reel of brass or other wire above your work and have a takeup reel below the work. The speed is adjusted so that the wire will erode and get "used up" at an acceptable rate. Wires are typically from two to ten mils in diameter.

With *small hole EDM*, tiny holes can be "drilled" very deeply and very accurately. One obvious use for small
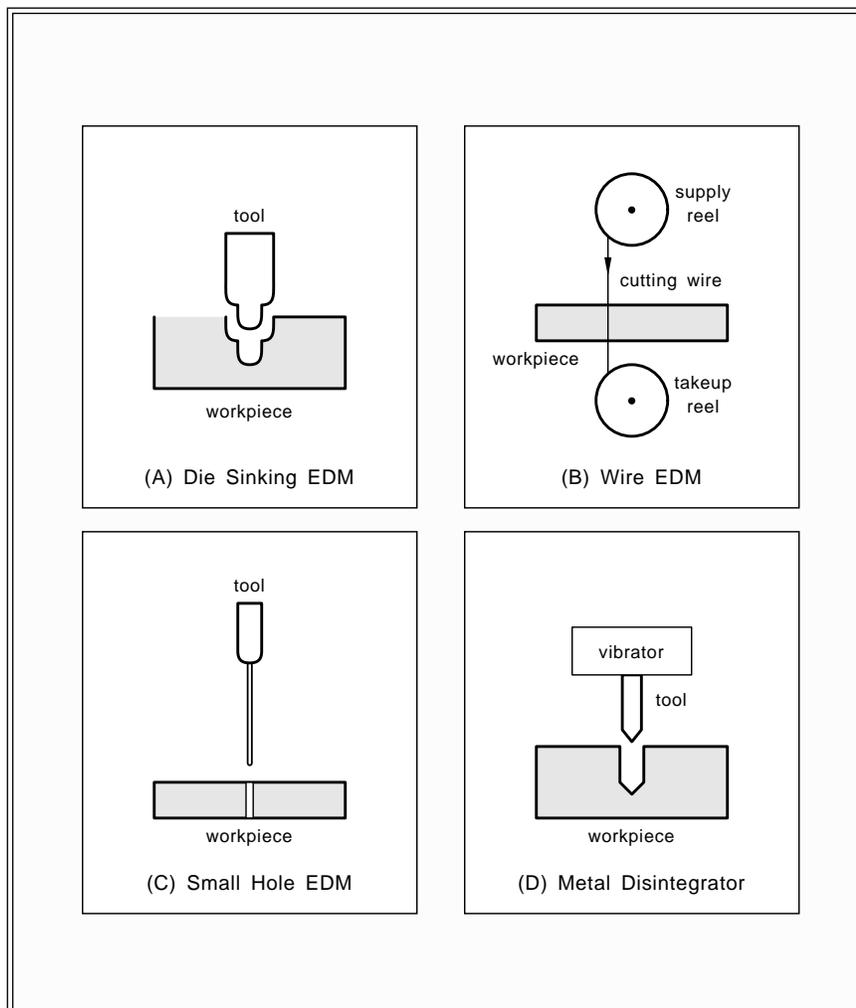
Fig. 4 – FOUR POPULAR VARIATIONS on Electrical Discharge Machining.

hole EDM is for drilling pilot holes to start an internal path wire for EDM machining process.

Finally, a *metal disintegrator* is a coarser EDM process which uses a vibrating electrode and an arc welder to literally blast some holes into your workpiece. Important uses are to remove snapped studs, stuck taps, or broken drills.

There's several unique advantages to EDM. The tool can be much softer than the workpiece, so you can now routinely use brass, copper, or carbon to cut up hardened steel, titanium, or carbide alloys. Ideally, there is zero tool contact, so there is no friction, chatter, or side loading.

By chosing the correct discharge polarity, the workpiece erodes much faster than your tool. Since you can now temper or harden the workpiece *before* you machine, the final results can end up more accurate.

Those EDM tool paths can be very complex. You can easily pull such tricks as "drilling" a deep and blind square hole that has sharp bottom corners. With wire EDM, a punch and a die can be *simultaneously* cut from a single piece of steel, guaranteeing a perfect fit with exact clearances.

The disadvantages to EDM? Both the tool and your workpiece must be conductors. Tool life is fairly short. And the machining rates are rather slow, say a cubic inch an hour for die sinking or thirty square inches per hour for wire EDM. Thus, a job may take overnight, even using stacked work and multiple heads. But this easily automated process can be done largely unattended.

The voltages and currents needed are not that big a deal. Since your arc is less than a mil long, 80 volts or so is all you usually want. Typical EDM power needs are several kilowatts. Or roughly the same as a larger milling machine or lathe.

Spark repitition rates are usually 20,000 to 500,000 sparks per second.

Most EDM circuits use a variation of the simple *relaxation oscillator*. Sort of a big brudder to the neon lamp flasher circuit we have shown you in figure five.

In any relaxation oscillator, your capacitor will slowly charge up to its critical voltage which breaks down or turns on some nonlinear switch such

as the gas plasma or the breakdown of a tool's spark gap.

The capacitor normally continues discharging at high current until it

drops below a current threshold. At that point, your gas deionizes or the spark quits, and the capacitor is free to once again begin recharging. The

EDM (SPARK MACHINING) RESOURCES

Alsop Engineering
PO Box 3449
Kingston, NY 12401
(914) 338-0466

American Machinist
1100 Superior Avenue
Cleveland, OH 44114
(216) 696-7000

Barnes/Raymond
PO Box 586
Maumee, OH 43537
(800) 228-1156

Belmont Equipment Co
32035 Edward Avenue
Madison Heights, MI 48071
(313) 588-7011

Ebbco, Inc
35500 Mound Road
Sterling Heights, MI 48310
(313) 268-7000

EDM Today
1212 State Route 23
Butler, NJ 07405
(201) 838-3130

Gisco
100 Laser Court
Hauppauge, NY 11788
(516) 273-5353

Hansvedt Industries
803 Kettering Park
Urbana, IL 61801
(217) 384-5900

Hurco Manufacturing
One Technology Way
Indianapolis, IN 46268
(800) 441-1036

Ingersoll
1301 Eddy Avenue
Rockford, IL 61103
(815) 654-5800

Lindsay Publications
PO Box 538
Bradley, IL 60915
(815) 935-5353

Metlfax
29100 Aurora Rd, Ste 200
Solon, OH 44139
(216) 248-1125

Mitsubishi EDM
1500 Michael Drive
Wood Dale, IL 60191
(708) 860-4210

Sodick Inc
710 Cooper Court
Schaumburg, IL 60173
(708) 310-2600

TRC Electronics
2216 West 16th Street
Broadview, IL 60153
(708) 681-1810

US EDM Systems
7960 S Roberts Road
Bridgeview, IL 60455
(800) 837-6808

Fig. 5 – THE CLASSIC NEON LAMP relaxation oscillator. The lamp flashes several times a second. Some EDM circuits use a much faster and far more powerful version of this circuit, substituting the tool spark gap for the neon gas breakdown.

cycle then repeats.

Typical EDM capacitors are in the 50 microfarad region. The value of the capacitor determines the size for each spark crater, thus trading off the smoothness against the cutting time. High quality capacitors having a low ESR series resistance are an absolute must. Electrolytics are a no-no.

An EDM machine can also be a spark gap transmitter that generates a horrendous amount of very bad radio interference. The usual shielding and other tricks are a must to get RFI down to acceptable levels.

In modern EDM, triacs or other electronic switches can speed up and improve the operation of the simple relaxation oscillator. But the idea is still the same. Charge a capacitor to spark breakdown. Then discharge the capacitor into the spark gap. Repeat the cycle over and over again. Spark times and duty cycles are adjustable over a wide range.

As our resource sidebar for this month, I've gathered together some places to go for more info on EDM. The leading trade journal is called *EDM Today*, while ads and articles occasionally show up in *American Machinist* and *Metalfax*. Besides all the other great machinery and home shop books, the *Lindsay Publications* folks offer a *Practice and Theory of Electrochemical Machining*, and the *Ramah Machine Metal Disintegrator*. Several other resources listed form a random sampling of higher profile manufacturers and distributors for EDM machinery and supplies.

Let's have your thoughts on new low cost hacker EDM opportunities. There should be lots of exciting new possibilities here. Especially with the latest of electronic switching power supply techniques.

New Tech Lit

There's loads of interesting new chips piling up. Particularly the *Aria* sound circuits from *Sierra*, or that new TMC22190 digital video layering engine and the TMC22070 genlocking video digitizer from *TRW*.

A multimedia stereo audio mixer ap note is now offered by the *Analog Devices* folks.

The *Black Book Official Auction Report* is sort of like a car blue book for shop machinery. This also lists bunches of auction houses likely to conduct electronic auctions.

A great cable and television station tabloid tech mag is *TV Technology*. Among other stuff, it's got lots of ads for toaster support products. And a similar pub for commercial radio stations is called *Radio World*.

For all the fundamentals of digital integrated circuits, be sure to check into my *TTL Cookbook* and *CMOS Cookbook*. Autographed copies per my nearby *Synergetics* ad. And my NUTS10.PS on *GEnie* PSRT offers a brand new tutorial on *PostScript for Hardware Hackers*.

Our new *Synergetics Consultant's Network* is also now up and running. Do give me a call at (602) 428-4073 if you want to participate on this or need any info on any other technical topic. Let's hear from you. ❖

Don Lancaster's
Hardware Hacker

March, 1993

History often repeats itself. First as a tragedy and then as a farce. It sure amazes me how many hardware hackers and software types refuse to learn from the past.

For instance, over a decade ago, the Apple II community conclusively proved beyond a shadow of a doubt that *copy protection does not work.*

Never did and never will.

Neither do the hardware dongles or similar add-ons. Yet many IBM and PC compatible folks are hell-bent on wasting new time, dollars, and energy reproving this fundamental truth to themselves. You will find only three known effects of copy protection: (A) It hacks off and inconveniences your legitimate users, sending them all to unlocked competitive products; (B) It diverts time and energy that is best spent improving and updating your code; And, of course, (C) Any copy protection dramatically *increases* the number of the bootleg copies of your product that get circulated.

The reason for C is simple. Copy protection *always* attracts attention to itself, causing scads of ultra-creative people to devote countless hours of time and energy towards cracking the secrets of your product.

Your bottom line is this: Undoing copy protection is *fun*! Not only is it challenging fun, it is by far the fastest and most cost effective way to learn machine language programming. And one of the best and the cheapest high quality learning experiences you will find anywhere ever.

Not to mention offering positively superb entertainment value.

On most hardware offerings, even grinding a part number off the key integrated circuit will have the exact opposite of the intended effect: All this does is cause lots of high energy people to puzzle out what the chip is and where to get one. The universal hacker popularity for that BA1404 stereo FM broadcaster can be directly traced to one firm stupidly grinding off one too many part numbers.

By far the most absurd notion on

hardware copy protection to recently resurrect itself is to…

Pot it in epoxy!

I simply can't believe the number of calls and letters I've gotten on this lately. Back in the late 1950's, it was conclusively seen that potting your circuits in epoxy in no manner offers any design secrecy whatsoever. In fact, epoxy potting will *always* have the exact opposite effect.

First, any reasonably good design engineer could select a "black box" approach and carefully look at the inputs and the outputs of the circuit. From the circuit's size, cost, and from being aware of trade journals, data books, distributor's catalogs, and ap

notes, they can easily come up with three or four methods to provide the same function.

At least one of which will end up far cheaper, better, and more creative than yours.

Second, it's a real trivial matter to X-ray any potted project. Free even, if it is a small module and you visit a reasonably curious dentist.

Third, most of the epoxy sources also supply *epoxy strippers*. These cheaply, rapidly, and conveniently dissolve out the potting compound, so it can be quickly washed away.

Fourth, epoxy could have several disruptive effects on your circuits. It changes the heat distribution and the operating temperatures. It can subtly

MATERIAL	RESISTIVITY measured in $\mu\Omega$-cm	RESISTIVITY as compared to copper
Aluminum	2.8	1.64
Brass	7.0	4.07
Constantan	44.1	25.60
Copper	1.7	1.00
German Silver	33.0	19.18
Gold	2.4	1.42
Invar	81.0	47.00
Iron	10.0	5.81
Lead	22.0	12.79
Magnesium	4.6	2.67
Molybdenum	5.7	3.31
Music wire	11.8	6.86
Monel	42.0	24.40
Nichrome	150.0	87.20
Nickel	7.8	4.53
Platinum	10.0	5.81
Silver	1.6	0.95
Tantalum	15.5	9.01
Tin	11.5	6.69
Tungsten	5.5	3.20
Zinc	5.7	3.34

Fig. 1 – THE RESISTIVITY FOR ANY MATERIAL gets defined as the face-to-face electrical resistance of a unit cube. Here are several resistivity values for some of the more popular metals and alloys.

MATERIAL	10 gauge	20 gauge	30 gauge	40 gauge
Aluminum	2	17	169	1720
Brass	4	41	419	4260
Constantan	26	260	2640	26,800
Copper	1	10	103	1050
German Silver	19	194	1970	20,100
Gold	1	14	141	1480
Invar	47	477	4850	49,300
Iron	6	59	598	6080
Lead	13	130	1320	13,400
Magnesium	3	27	275	2800
Molybdenum	3	34	341	3470
Music wire	7	70	706	7180
Monel	24	247	2451	25,600
Nichrome	65	659	6750	70,240
Nickel	5	46	467	4750
Platinum	6	59	598	6080
Silver	1	10	98	991
Tantalum	9	91	928	9430
Tin	7	68	688	7002
Tungsten	3	32	330	3350
Zinc	3	33	344	3450

Values in milliohms per foot ~or~ Ohms per 1000 feet.

Fig. 2 – SOME TYPICAL RESISTANCE VALUES for different materials and wire gauges.

detune polystyrene capacitors. Its weight shifts mechanical resonances to more destructive frequencies.

Fifth, a very little known fact: The ferrite rf beads used on typical high frequency analog circuits *must* be able to change their size slightly or they will not work properly. The high frequency energy gets absorbed by a magnetostriction that in turn converts to heat. Locking ferrite beads in an epoxy can alter their response.

Used with care, there are times and places where the epoxy potting is an appropriate technique. Especially for water resistance or use in hazardous environments. But epoxy potting for copy protection just does not work.

Getting "Nichrome" wire

I've gotten several calls and letters recently wanting hacker sources for "Nichrome" wire. I'll show you some sources and alternates in just a bit.

But please note that "Nichrome" is one particular brand of one particular formulation of what is more properly called *resistance wire*.

Most often, you'll want all of your electrical or electronic wires to be very efficient. And wasting as little energy and producing as little heat as possible. But there are other times and places when you want to cause a wire to intentionally generate heat or create a specific voltage drop.

Obvious examples include toasters, electric blankets, hot wire plastic or foam cutters, laminating machines, space heaters, soldering irons, motor starters, thermal relays, refrigerator defrosters, or for dummy transmitter loads. Some non-obvious places for carefully controlled resistance in wire format include current meter shunts and sensors that turn your printer on whenever you power your computer.

Most elements, alloys, and other materials group themselves into four types. *Conductors* can pass electricity fairly easily and have low resistances. Conductors can include both ordinary wire and resistance wire.

Semiconductors offer a moderately high resistance to electrical currents, with silicon and germanium being the most obvious examples. *Insulators* offer very high resistance to electrical current. Rubber, glass, plastics, and ceramics are typical insulators.

And, finally, the *Superconductors* can offer zero resistance to electrical currents. But all superconductors are restricted to exotic formulations and special conditions under extremely low temperatures. You'll find more on superconductors in the *Hardware Hacker II* reprints.

Take a one centimeter cube of any element, alloy, or material. Next, you apply a voltage from full face to the opposite full face. Then measure the current. By Ohm's Law, the ratio of the voltage to current determines the *resistance* of the cube. But we have a special name for the resistance of a unit cube. This is the *resistivity*, and is shown by ρ, the Greek letter *rho*.

The resistance of a wire increases with its length and will decrease in proportion to its area. The metric resistivity units are Ohm-centimeters^2 per centimeter, or Ohm-centimeters. I'll use a wondrously oddball unit of *microOhm-centimeters* ($\mu\Omega$-cm) here so our numbers look nicer.

Resistivity values let us compare materials *independent of their actual sizes*. Some popular resistivity values are shown in figure one, while figure two shows you how much resistance you can expect for various wire sizes of selected materials.

The lowest resistivity of common elements or alloys is silver, checking in at 1.6 $\mu\Omega$-cm. But silver is fairly rare and readily tarnishes, and the commodity price of silver changes all over the lot. So, silver isn't used too much except for RFI suppression and exotic military stuff.

Copper, of course, is the universal best choice in a conductor. It has a resistivity of a mere 1.7 $\mu\Omega$-cm. Only five percent worse than silver.

At first glance, aluminum appears almost as good as copper, having a conductivity only 64 percent worse. In theory, the thicker but cheaper and

lighter aluminum conductors could be substituted.

But aluminum has a pair of nasty habits which include electrochemical decomposition and the building up of sapphire hard (literally!) tough oxide coatings. Making a solid connection to an aluminum wire is not a trivial task. Several decades ago, a bunch of house trailers burned up after some abortive attempts at trying to perfect aluminum wiring.

Most of the other popular elements and alloys have resistivities that are moderately higher than copper. But a magic alloy of 61 percent nickel, 24 percent iron, and 15 percent chrome provides a resistivity over fifty times higher than copper. When combined with its other useful properties, this *Nichrome* alloy makes an outstanding resistance wire.

Figure two shows you how much resistance to expect for various wire sizes for each of these materials. A foot of 20 gauge Nichrome wire has a resistance of 0.659 ohms. The same alloy in 30 gauge provides around 6.75 ohms total.

Resistance wire gets measured in ohms per thousand feet. Or you may prefer its equivalent of milliohms per foot. Naturally, resistance wire works just like any other resistor, obeying Ohm's law and the usual…

$$P = E^2/R$$

power relations. A watt of electricity is, of course, a watt of heat. And a BTU of heat equals 17.58 watts. So you can easily calculate the amount of heat you should generate. As a reminder, a BTU or *British Thermal Unit* is the amount of heat needed to raise the temperature of one pound of water by one degree Farenheit.

Other resistance wire parameters do include the tensile strength, the temperature coefficient of resistance, and the temperature coefficient of expansion. The resistance tempco gets important fast in such things as meter shunts. The expansion tempco becomes crucial when you are going through some ceramic seal. Should the wire and the ceramic expand at different rates, you can self destruct at high temperatures.

The fastest and simplest way to get some Nichrome wire to play with is to gently crush up a surplus power

resistor in a vise and unwind the wire. Different sizes offer different lengths and gauges of wire. Resistance wire often ends up available surplus at bargain prices, especially at *Fair Radio Sales. American Science and Surplus* also offers cheap resistance wires. Originally used as refrigerator defroster elements.

One big supplier of new resistance wire is *MWS Wire Industries*. Their equivalent to "Nichrome" is known as MWS-675. They also offer two dozen other variations. Their MWS-875 provides even higher resistivity with better tempcos for both resistance and expansion. This alloy uses chrome, aluminum, and iron, with traces of added carbon and silicon. It is also slightly lighter in weight.

By the way, other trade names for *Nichrome* are *Trophet C*, *Alloy C*, *HAI-NiCr60*, *Chromel C*, *Nikrothal 6*, and *Electroloy*.

For this month's contest, just tell me about a new or unusual hacker use for resistance wire. There'll be all of the normal *Incredible Secret Money Machine II* book prizes, along with an

all expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the best submission of all.

As usual, send your written entries to me here at *Synergetics* and not to **Electronics Now** editorial.

A hacker's part 68 telephone interface

In several past columns, we have looked at the FCC part 68 Interfaces . These are required any time you want to put voice, music, caller id data, or modem tones on or off of the phone line. The key component needed is just a fancy transformer with a high isolation voltage rating, a very good balance, and the ability to accept dc primary current.

There are lots of dollars, time, and effort needed to get an interface FCC type approved. And it is now illegal to make any connection to the phone line without going through an *FCC* approved Part 68 interface . At least in the US.

Several firms now offer "pass thru" interfaces that you can include within your own circuits to get an instant
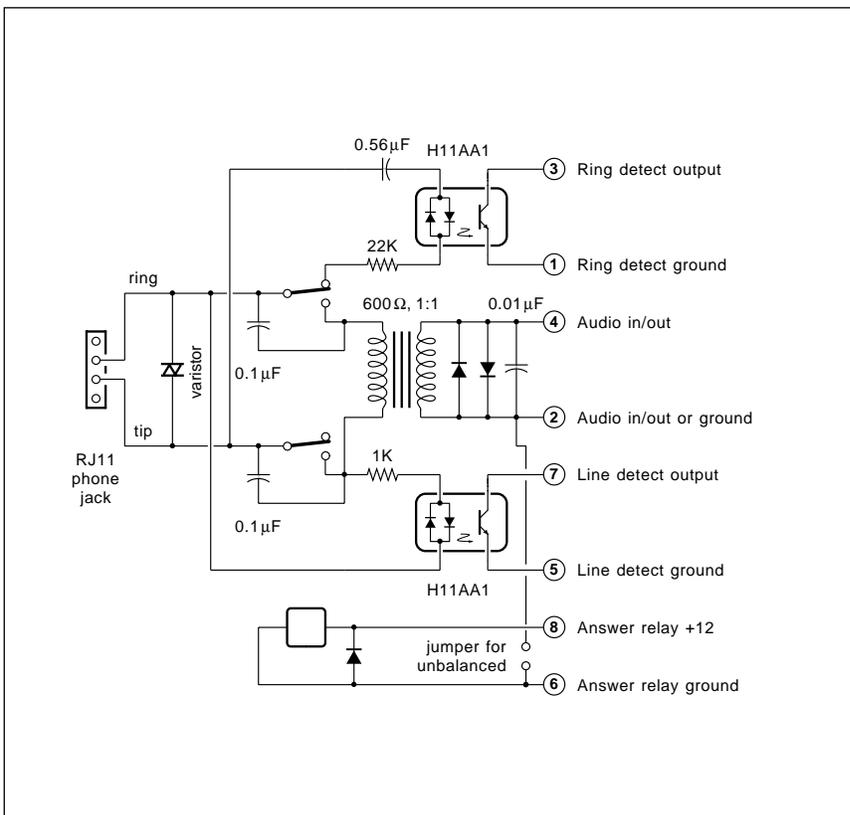
Fig. 3 – THE CIRCUITWERKES MPC-2 is a FCC Part 68 telephone interface that offers a "pass through" type approval for your own hacker projects.

and automatic type approval. The two major suppliers are now *Cermetek* and *Dallas Semiconductor*. Sadly, their pricing has been too high for most hacker uses.

A startup outfit by the name of *CircuitWerkes* is now offering a new and hacker friendly Part 68 interface at a user acceptable price of $29.95. And yes, it offers a full type approval pass thru. Subject only to a few easy rules that involve component spacing, labels, docs, and mods.

Figure three shows you the circuit.

A small relay decides the *on-hook* and the *off-hook* states. To "sieze" or "answer" the line, you apply 12 volts dc to the relay, providing 60 mils.

The ring detector circuit is active only when on hook. This consists of a optoisolator that responds to the high ac ringing voltage, typically 140 volts at a frequency of 28 to 40 Hertz. The output of the ring detector is an open collector. You'll have to provide both an external pullup resistor and a filter capacitor to ground. Suitable values are 12 K and 5 microfarads.

The main data path is active both on and off hook. This dual feature is needed for a caller id compatibility. When you are on hook, the data path is capacitor coupled.

When off hook, the data path gets dc coupled through the transformer primary. A second optoisolator in parallel with the primary acts as a line current detector. The line current gets detected by monitoring your dc *voltage* drop across the primary.

The line current detection lets you know when your calling party hangs up. This optoisolator also offers open collector output. A pullup resistor is also required here.

The main data path is just a special transformer with two clipping diodes to limit your maximum applied audio. A jumper option allows you to select a balanced or single ended 600 ohm source/sink for your audio.

Typically, your computer will first monitor the ring detector. After a ring, it siezes the line and optionally grabs the caller id tones. Then it will send or receive your voice or data. Finally, you can hang up by dropping out the relay. Either by detecting the absence of line current or by hanging up on purpose.

As a second contest for this month,

just tell me about a new or unusual application for a hacker legal Part 68 interface project.

Much more info on those caller id applications appears in a dozen files on my *GEnie* PSRT.

More semiconductor resources

We will wrap up our continuing listing of the major semiconductor houses in a third and final sidebar.

This month, we will cover *OKI* up through *Zilog*. I've tried to zero in on those suppliers of the greatest hacker interest. Let me know if I missed any of your favorites.

A complete list will appear in the *Hardware Hacker IV* reprints. I've also gathered them together into the ICMFGRS.PS download you'll find on *GEnie* PSRT.

As we have seen before, your best bet here is to request a short form catalog, the price list, and a literature directory. Be absolutely sure to use professionally sounding phone calls or your own custom PostScript laser letterhead. A ball-point-pen on tablet paper flat out won't hack it. Much more on finding and using tech info are in my newly revised *Incredible Secret Money Machine II*.

New tech lit

We have got some really exciting new publications for this month. The first is Dick Oliver's new *Nonlinear Nonsense*, a free quarterly newsletter on fractal modeling, chaos science, artifical life, and creative graphics. His 3-D fractal design software is also commercially offered.

Also free on professional request is the new *Spread Spectrum Handbook* from *Stanford Telecomm*. This is a dozen pages of ap-notes and useful references, along with bunches of data sheets for their high-end digital spread spectrum chips.

The *Scrambling News* has detailed insider information on the current tv video scrambling and descrambling methods. They also offer books full of schematics, mods and related tech info. A competing newsletter is the *Satellite Watch News*.

The *SRS Encoder* is a new monthly newsletter from the *Seattle Robotics Society*. Lots of regional info on great surplus buys here.

And Joe Singers *Printer's Devil* is

NAMES AND NUMBERS

American Science & Surplus
601 Linden Place
Evanston, IL 60202
(708) 475-8440

Cermetek
1308 Borregas Avenue
Sunnyvale, CA 94089
(408) 752-5000

CircuitWerkes
6212 Southwest 8th Place
Gainesville, FL 32607
(904) 331-5999

Dallas Semiconductor
4401 Beltwood Pkwy South
Dallas, TX 75244
(214) 450-0400

Fair Radio Sales
PO Box 1105
Lima, OH 45802
(419) 227-6573

GEnie
401 N Washington Street
Rockville, MD 20850
(800) 638-9636

Lor'd Industries Limited
Box 156
Hancock, WI 54943
(715) 249-5611

MWS Wire Industries
31200 Cedar Valley Drive
Westlake Village, CA 91362
(818) 991-8553

Nonlinear Nonsense
Route 1 Box 5140
Morrisville, VT 05661
(802) 888-5275

Printer's Devil
PO Box 66
Harrison, ID 83833
(208) 689-3738

Satellite Watch News
6599 Commerce Court, #103
Gainesville, VA 22065
(703) 347-7926

Scrambling News
1552 Hertel Avenue
Buffalo, NY 14216
(716) 874-2088

SRS Encoder
PO Box 30668
Seattle, WA 98103
(206) 362-5267 [E-mail]

Stanford Telecomm
2421 Mission College Blvd
Santa Clara, CA 95054
(408) 748-1010

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a superb alternative publication on home printing and presswork. "A press in every home; a home in every press." Quarterly at a bargain $10 per year sub price.

Finally, the New Age Alternatives Discount Catalog is another resource for pseudoscience devices and info. Fascinating reading fer sure. This one is offered by *Lor'd Industries*.

We've previously seen that *High Energy Enterprises* and *Borderland Sciences* are additonal pseudoscience supply houses. It sould would be interesting to put together a master directory for all of these. Again, I feel they make some absolutely incredible reading. Some of the locals around here actually believe in all this stuff. And, amazingly, it does seem to work for them. Or so they claim.

For now, though, I'll stick with my "Looks like a duck, quacks like a duck" filter. Boy, a whole flock of 'em flew over that time.

Misquoting Sagan, extra-ordinary

claims always demand extra-ordinary evidence. Most especially when any known physical laws are flagrantly violated. An independently testable and fully reproducible experiment is always the key you should watch for.

A reminder here that I have got reprints available for most of my columns. Both in *Book-on-demand* published hard copy and on line at *GEnie* PSRT. The titles now include my *Ask the Guru*, *Hardware Hacker*, the *Blatant Opportunist*, *LaserWriter Secrets* and the new *Resource Bin*. Check my nearby *Synergetics* ad for more details.

As usual, I have gathered most of the mentioned resources together into both of our *Names and Numbers* and the *Semiconductor Manufacturer's III* sidebars. Do be sure to look here first. Also as usual, you can get tech help, consultant referrals, and lots of off-the-wall networking by calling my tech helpline.

Let's hear from you. ❖

Don Lancaster's
Hardware Hacker

March, 1993

Let's start with some updates to our earlier columns. Yet another approach to the $5 Navicube is a plain old low cost mechanical gyro. Which is the route that *Gyration* has chosen with their unique *GyroPoint* system. Their entire gyro is the size of a film can. It has been designed from the ground up for consumer apps.

Prototype costs, of course, are still totally outrageous. To me, spinning wheels do seem a hopelessly outdated interim solution at best. There's no doubt that micromachined silicon is ultimately the only way to go.

The CEO of a traditional gyro firm has assured me that it was "absolutely impossible" to create a $5 rate gyro. Well, there are flat out far too many emerging applications that *demand* a $5 gyro replacement. The paradigm *has* shifted, and the time is long past due for stunning cost reductions here. The choice a traditional gyro CEO has is simple: Bring out this inevitable product by yourself.

Or else go down in flames.

Here are two more Asian electronic resources: There's now an *EDN Asia* version of this popular trade journal. The *Hong Kong Trade Development Council* has a toll-free number which lists 52,000 manufacturers, importers, and exporters. Some other assistance is also available.

Cubic splines

There are lots of times and places where you would like a machine or a computer to create a graceful curve. Perhaps with a CAD/CAM mill, on an engineering graph, in a 3-D surface modeler, vinyl signcutter, or for any other typography, plain or fancy.

I have recently been exploring a really great scheme to elegantly deal with graceful curves. These are called *cubic splines*. They sometimes do get called *Bézier* curves, after the French mathematician who explored them.

What do we ask of a curve drawing method? First and foremost, it should look good. Second, we want it to be largely *device independent*, working

(A) Here is a cubic spline shown in its *graph space*...

influence point #1

influence point #2

(x_1,y_1)

(x_2,y_2)

The first influence point sets the direction and enthusiasm that the spline leaves the initial point of the curve.

The second influence point sets the direction and enthusiasm that the spline enters the final point of the curve.

(x_3,y_3)

(x_0,y_0)

initial point
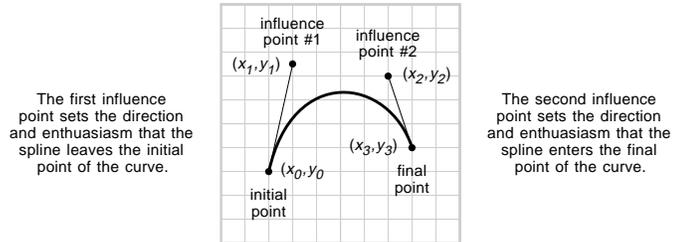
final point

(B) Here is how a cubic spline appears in its *equation space*...

$$x = At^3 + Bt^2 + Ct + D$$
$$y = Et^3 + Ft^2 + Gt + H$$

t (or time) always goes from zero at the initial point to one at the final point

(C) A faster "cube-free" form of the *equation space* math...

$$x = (((At) + B)t + C)t + D$$
$$y = (((Et) + F)t + G)t + H$$

(D) How to get from graph space to equation space...

$A = x_3 - 3x_2 + 3x_1 - x_0$ $E = y_3 - 3y_2 + 3y_1 - y_0$

$B = 3x_2 - 6x_1 + 3x_0$ $F = 3y_2 - 6y_1 + 3y_0$

$C = 3x_1 - 3x_0$ $G = 3y_1 - 3y_0$

$D = x_0$ $H = y_0$

(E) How to get from equation space to graph space...

$x_0 = D$ $y_0 = H$

$x_1 = D + C/3$ $y_1 = H + G/3$

$x_2 = D + 2C/3 + B/3$ $y_2 = Y + 2G/3 + F/3$

$x_3 = D + C + B + A$ $y_3 = H + G + F + E$

(F) Some cubic spline tools available on *GEnie PSRT*...

#606	GNZOTRX2.GPS	New TEX-like Guru Gonzo utilities
#605	BEZIER1.PS	Distance from point to Bézier curve
#590	BEZIER.PS	Bézier curve fast evaluation.
#588	FUZZYBEZ.PS	Bézier curve from fuzzy data (!)
#530	SPHERE.PS	PS spherical nonlinear mapper
#214	GURU68.TXT	Bézier curvetracing fundamentals
#205	NUBANNER.FNT	Fast & accurate parade banner freefont
#202	TWIXTBEZ.FNT	Flagwaver freefont & Bézier ct utility
#161	SLEEZOID.PS	Avuncular sleezoid utility
#190	BEZLNGTH.PS	Bézier curve length utility
#077	MEOWWRRR.PS	PostScript puss de resistance

Fig. 1 – CUBIC SPLINES are a useful and convient way of handling smooth and graceful curves by using a sparse data set. Here are several of the fundamentals you will need to start exploring these on your own.
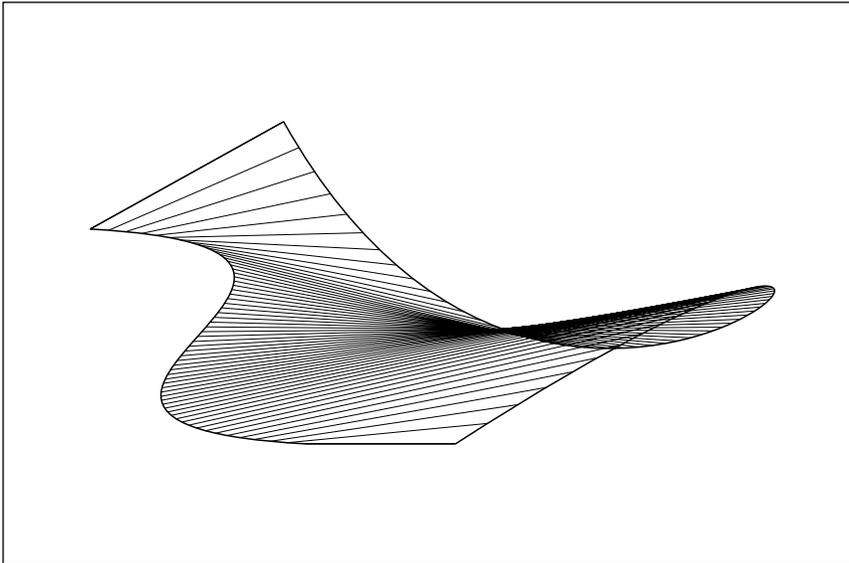
Fig. 2 – THIS AVUNCULAR SLEEZOID is a just-for-fun example of how you can stop anywhere along a cubic spline. Note how the "t" parameter changes "faster" along the "more bent" portions of the curve.

the exact same way for video screens, laser printers, typesetters, embroidery machines, or whatever. All done from the *same* ordinary textfile.

Third, we'll want it to use *sparse data*, easily described by using only a few size-independent values. Fourth, we'll want to be able to splice simple splines together into more complex curves without serious glitches.

Fifth and finally, we want it to be reasonably fast and easy to compute. And easy to understand.

The simplest way to build a curve is the *step method*. Where you move over a click and up one notch. Keep repeating with different sized clicks and notches until you step yourself along the entire curve. You make the clicks and notches small enough for "smooth" results, but big enough that you don't need a zillion of them.

Better yet, do your clicking and notching at the same time, by using a *vector* or *stroke* method that's able to approximate your curve with straight line segments. This looks a lot better than the step method, but there are still joint breaks. And an incredible amount of detail work is needed.

A fancier approach is to use little broken pieces of parabolas. This is the *quadratic spline* or *second order curvefit* method. But lots of pieces are still needed, and the results flat out do not look all that great. Which

is one of many reasons that TrueType fonts are inferior to PostScript fonts. More on this another time.

I feel the "best" method for simple and graceful curves involves using a *cubic spline* technique.

There are two ways of looking at cubic splines, and you'll have to use both of them for full control. You can work in your *graph space*, where you are actually looking at the spline. Or you can work in your *equation space*, where you can precisely control your underlying math.

Figure one first shows you a cubic spline in its graph space. Regardless of its size, only *four* points (or eight x-y data values) are needed to fully specify the spline…

The *initial point* at x_0, y_0 tells you where the spline *starts*.

The *final point* at x_3, y_3 tells you where the spline *ends*.

The *first influence point* at x_1, y_1 should set the *direction* and *enthusiasm* with which your curve *leaves* the initial point.

The *second influence point* at x_2, y_2 should set the *direction* and the *enthusiasm* that your curve *enters* the final point.

Other names for the enthusiasm are the *tension* or the *velocity*.

A line connecting the initial point and first influence point defines the initial *tangent* direction used by the spline. The first tiny step along your spline should *always* head out in this direction. Similarly, a line connecting the second influence point and the final point defines the final *tangent* direction for your spline.

To build a cubic spline in the graph space, you set your end points. Then you move the influence points around to stretch and squeeze the spline into its intended shape. Typically, your influence points are well away from the curve itself.

Just like any middle management magician, you will find limits to the rabbits a single cubic spline can pull out of its hat. One spline can get you any straight line or smoothly curved path; some smooth curves having at most one *inflection* point (such as a sinewave); some curves with a single *cusp* (or "point"); or certain curves having one single and simple loop in them. All of which are both graceful and sparsely defined.

For fancier stuff, you use several splines end-to-end. We'll see more on this shortly.

Figure one also shows you a cubic spline in its equation space. Instead of relating *x* to *y*, you instead relate them *both* to a new *parameter t*. You could think of *t* as *time*. *t* will *always* range precisely from *zero* to *one* as your spline smoothly moves from its initial point to its final point.

One interesting way to look at the cubic splines is to think of a box in *x*, *y*, and *t* space. Inside the box is a three dimensional snake-like curve. Look in the *xy* end of the box and you will see your spline. Look in the *yt* side, and you will see how *y* varies as *t* (or time) goes from 0 to 1. Or look down through the *xt* top to see how varies, again as *t* goes from 0 to 1.

Note that *x* and *y* are independent of each other. Each gets separately defined in terms of *t*. Knowing one does *not* reveal you the other. Unless you find *t* first. Do note that *t* usually does *not* move uniformly along your curve. Instead *t* tends to move faster along the "more bent" portions of the curve. And moves slower along your straighter portions.

Bopping between the equation and graph space is the key to controlling

your splines. Figure one also shows you the simple ninth grade algebra needed to get from those influence points to the math equations, and vice versa. For some strange reason, this simple and obvious two-way math is very hard to find.

Let's repeat the basic cubic spline equations here…

$$x = At^3 + Bt^2 + Ct + D$$
$$y = Et^3 + Ft^2 + Gt + H$$

Once again, t goes from zero to one as you go from the beginning to the end of your spline.

The obvious reason we call these cubic splines is that your highest power of *t* involved is a third power cube. The cubic term has most of its effect on the *final end* of your curve. The quartic (squared) term does most of its useful work in the *middle*. The linear term sets the initial *slope*, and the final D value sets your *offset*. By suitably combining these four terms, a wide and useful variety of spline curves can be generated.

But doesn't cubing sometime take forever on typical computers? Well, you can get sneaky and eliminate any need for raising anything to the third power. Instead of calculating each individual coefficient, what you do is rearrange the original equations as…

$$x = (((At) + B)t) + C)t + D$$
$$y = (((Et) + F)t) + G)t + H$$

Or, restating things in English, to fake cubing, take A and multiply it by *t*. Add B. Multiply by *t* again. Add C. Multiply by *t* again. And, finally, add D. Presto. A cubeless cube.

Inside the machine or computer, the actual details of getting from any cubic spline to a frame bitmap or the tool paths will vary. But, in general, all you will do is repetitively use the simple algebra of figure one to decide where you go next. Consistent with your available step resolution.

Getting fancy

Although you might use any old computer language to explore cubic splines, I've found that the general purpose PostScript language is by far the fastest, easiest, and most fun way to play with Bézier curves. I've now posted a group of Bézier and cubic spline exploration tools to my *GEnie* PSRT. A few of these are also listed

for you in figure one.

For instance, following a suitable scaling and translation, here is how you request the figure one spline in PostScript…

> *2 3 moveto*
> *3 7.5 7 7 8 4 curveto*
> *stroke*

Note that only a few dozen bytes are needed to *fully* specify the spline, *regardless of its final size or device resolution!* This is sparse data used at its very best.

By the way, if you don't yet have real PostScript, we now do offer the shareware GHOSTSCRIPT emulator on PSRT. Which runs fake PostScript on nearly *any* printer or on nearly *any* computer screen. Yes, the full source code is included.

Does a cubic spline have a length? Well, obviously. But only if you are not a mathematician. Go through the length math, and a big ugly square root of some fourth order polynomial (which is *much* worse than it sounds) should leap out at you. After years of

careful asking, I have yet to find *any* simple and exact closed form solution for the length of a cubic spline.

Yet, knowing the length of a spline gets *very* interesting for positioning typography on a curved surface, to fit fuzzy data, for correcting or creating distortions, or for that just-for-fun *avuncular sleezoid* surface you will find in figure two.

So, what I'll do instead is chop up any cubic spline into a hundred or so pieces. You then assume each piece is a straight line, and add their lengths up. Your answer is typically good enough for most graphical uses. And a mere hundred points usually gives you better than one part per thousand final accuracy.

By the way, if you do know how to quickly and conveniently find me the exact length of a cubic spline, please let me know. A free *Incredible Secret Money Machine II* for your trouble. Every math freak that I've talked to insists this is impossible. They have almost convinced me.

Things get interesting when you

Fig. 3 – CURVETRACED CUBIC SPLINES are ideal for animation and cartoon characters, such as the "puss de resistance" shown here. Only a word processor is needed to create this quality artwork. No scanner is used.

splice cubic splines together. This is how you build fancy typography and other complex shapes. Ideally, you want to at least match your end points and your end point slopes. The rate of change of the curvature at each joint should also be constant, but this gets nasty in a hurry.

Picking the points gets tricky. Try to go too far with each spline and you lose accuracy. Don't go far enough, and you need too many splines and the splines may become very noise sensitive. Creating nervous results.

I've written a simple *curve tracing* routine that's now in my *PostScript Secrets* book/disk combo. You throw some endpoints and slopes at it, and it builds up all of your splines for you. Curvetracing is really great for high quality digitized signatures that need only tiny file sizes.

Curve tracing is also superb for animation. Figure three shows you *Meowwrrr*, our *Synergetics* puss de

resistance. Curvetracing can give you precise and sharp results.

Only a word processor is needed; there's no scanning involved. I have included a full curvetracing toolkit in my #517 GONZO15A.PTL.

Ideally, you sure would like to just throw some fancy and noisy artwork at a cubic spline generator and have it automatically pick how many splines to use to produce the "best" possible results. This is not trivial, especially with noisy data.

You first have to decide how long each spline is to be and where it is to go. Then, you'll most often want to *constrain* all the intermediate splines, controlling both the entry angles and entry points. Or otherwise restricting them for continuity.

The "horses' mouth" paper on all of this is *Curvefitting with piecewise parametric cubics* by Michael Plass and Maureen Stone (with a little help by some guy named Warnock). This

did appear in the July 1983 *Computer Graphics* pg. 229-239. And otherwise known as the SIGGRAPH Proceedings for 1983. The math here is unbearably heavy and obtuse.

So, I decided to take this general "fancy but noisy data into connected cubic splines" concept and have now generated somewhat similar results with #588 FUZZYBEZ.PS. Which will create the best smooth cubic spline through any noisy data while keeping your choice of constraints. Only ninth grade algebra is involved, and most of that gets fully automated. Speed is around five seconds per spline.

We will have several contests this month. To start off, either find me a simple Bézier length formula (lots of luck!), or show me a new and unusual task for cubic splines. Or curvetrace me something interesting.

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

Be sure to send your written entries to me at *Synergetics*, rather than to **Electronics Now** editorial. Any code can be directly uploaded to PSRT.

Non-ionizing radiation safety

Do power lines cause cancer? One recent movie and a lot of my helpline callers do seem quite concerned over this. As with any controversy, your first step is picking up accurate and unbiased data. And useful tools for your own research.

Start off with *Polarized Debate: EMF's and Cancer*. Found in *Science* for December 11, 1992, p. 1724-1725. This is an unbiased summary. There's also the *Microwave News: A Report on Non-Ionizing Radiation*. This one is both expensive and has an alarmist tone about it.

As usual, any ongoing scientific controversy can be followed via the *Dialog Information Service*. And any newer important papers are likely to appear in an *Electric Power Research Institute* report.

For instruments and components, two sources include *F. W. Bell* and *Walker Scientific*. And ads for similar products appear in that *Compliance Engineering* trade journal.

One little noted fact: While high voltage power lines sound strong and

nasty, their field strengths, expressed in *volts-per-mil* at sane distances, are *much lower* than your normal internal electrical human cell potentials. And overwhelmingly by far your largest magnetic field that you've ever been exposed to is the earth itself.

My own feelings are that if there were any major problems here, they would have become obvious a long time ago. There probably are some observable effects, but they probably do lie within acceptable risk bounds. And are reasonably avoidable.

On the other hand, rethinking some really dumb stuff (such as building new playgrounds under high voltage lines or sitting on a police radar) is probably a good idea. And utilities studiously avoiding any careful and unbiased research certainly is not. There is probably a hacker buck to be made providing low cost monitoring instruments. And possibly a science fair project or school paper in your own surveys.

I do have a hunch this will prove to be an example of billions of dollars being blown on what will ultimately prove to be a monumentally large non-problem. There are much more urgent and far more important things to be doing with your time and effort.

National's simple switcher

The *National Semiconductor* folks have been offering free sample kits of their new *simple switcher* series of voltage regulators. Figure four shows you a typical circuit. Only five parts are needed to take a raw 7-60 volts of input and provide a fixed +5 volts of output. Other chips in the series give other values of fixed or adjustable output. In step-up, or step-down, or polarity inverting circuits.

We've looked at these switchmode regulators in previous columns and in the *Hardware Hacker* reprints. The major advantage of any switchmode regulator is in its potential efficiency. Stepping 40 volts on down to 5 volts with a one amp linear regulator is at its best only 12.5 percent efficient.

For each watt of load power, you have to burn up an extra seven watts internally.

But a switching regulator can, in theory, be 100 percent efficient. And getting above 85 percent is very easy in the real world. Thus, you only burn
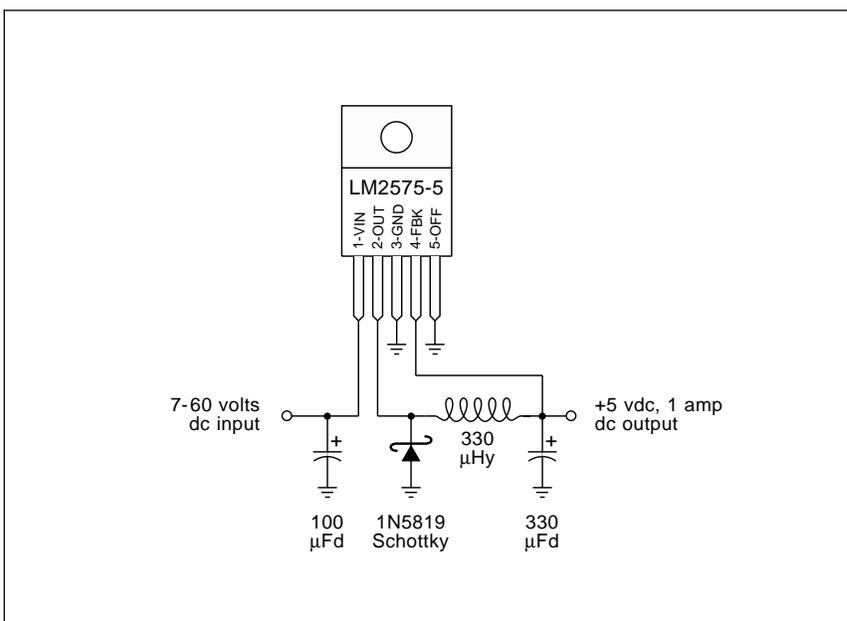
Fig. 4 – THE SIMPLE SWITCHER series of chips from National let you build an efficient switchmode regulator with only five parts. Heatsinking can often be eliminated completely. Free kits are available on professional request.

up around 150 milliwatts internally for each watt of load power. Which means less input power and less heat to get dumped. Heatsinks can often be eliminated entirely.

Any switching regulator does just that. It is a high speed switch that is rapidly turned on and off at a chosen duty cycle. Your duty cycle sets the average current through the output inductor, and thus your load current. A feedback loop adjusts how long the switch is on. During times the switch is off, a *freewheeling diode* continues the inductor's current path.

In our 40 volt input example, your switch is only on for one eighth of the time. Thus your average input current is only an eighth that of a comparable linear regulator. The frequency used is 50 kilohertz.

Full details appear on the related data sheets and ap notes. There's also a companion diskette that lets you optimize all your external component values. By the way, both the inductor and the freewheeling diode values are critical and *exact* brands and values *must* be used. The circuit simply will not work with an inductor having too high a dc resistance or one that ends up saturating at higher currents.

Similarly, ordinary silicon diodes are too slow and too inefficient.

Switchmode resources

For this month's resource sidebar, I have gathered together a few of the more obvious places to go for more information on these switching mode techniques. Not only for regulators, but also for motor controls and power inverters. The listing is mostly a mix of semiconductor houses who provide switchmode chips and a collection of the leading trade journals.

National's simple switcher is nice, but your best switchmode resource is *Maxim*, who have bunches of freebie samples and evaluation boards of an incredibly wide selection of voltage regulators and converters. Lots of ap notes, too.

Let me know if I've missed anyone important. There are scads of hacker opportunities here. Especially in the area of clean, stable, and lower cost power inverters. I'll try to have more circuits in future columns.

New tech lit

New *Electrorheological Fluids* are found in *Science* for October 30, 1992 on pages 761-766. These are fluids whose apparent viscosity can change with the applied voltage. Obvious aps would be clutches, 4WD-on-demand, and robotic muscles. Plus, of course,

being a just-obscure-enough student paper topic.

From *Philips*, their *Semiconductor Sensors Data Handbook*. It includes magnetic field sensors, temperature sensors, and proximity detectors. And through *TDK*, a similar *Sensors* short form catalog on devices for infrared, humidity, current, surface potential, and even powder levels.

An enormous and free *Wall Chart of Programmable Devices* from *Data I/O* lists just about all the EPROM's, EEPROM's, PLD's, and such.

Two trade journals of interest to any professional sound installers are the *Sound & Communications* and the *Sound & Video Contractor*.

A reminder that I stock just about all of the important PostScript books from all of the major authors. I have

even gathered together one each of everything into our PostScript *Whole Works* package. And much more on everything PostScript appears on my GEnie PSRT.

I've just added a new way to write fancy math equations in PostScript that includes some TEX-like features. See GNZOTRX2.PS for details. Or try HACK61.GPS for an editable copy of our figure one example.

Several helpline callers have asked for more info on *GEnie*. As always, you can call (800) 638-9636 for your local connect info. Because there are now thousands of nodes across the country, the chances are *very* good that *GEnie* access will be only a local call away. There are other low toll arrangements as well.

GEnie is not yet the largest of the

information utility, but it is widely regarded as having the most and the best in the way of superb technical downloads. At last count, there were some 130,000 files on line waiting for your immediate use.

GEnie uses the "two tier" pricing structure. For a basic rate of $5 per month, you pick up unlimited email, movie reviews, the airline schedules, dial-a-joke, stock market quotes and great heaping bunches more. For the value-added services, such as PSRT and most of the computer libraries, there is a $6 per hour surcharge. On PSRT, this usually translates to an average of twenty one cents or so per library download.

Other *GEnie* RoundTables that you might just find of interest are RADIO, MAC, IBM, A2-PRO, DTP (desktop publishing) and HOSB (home office and small business). Most boards offer downloadable libraries, current news, and on-line conferences. Plus all of those usual BBS message and question/answer exchanges.

Two tips: If you are downloading a tutorial textfile, or a new PostScript routine that you are reasonably good at troubleshooting, use (L)ist rather than XMODEM. Assuming, of course, that you have a decent modem and clean lines. Listing an uncompressed textfile is faster and cheaper than XMODEMing a compressed version. Naturally, XMODEM (or its improved offspring) should still be used on any file that must be absolutely correct.

If you are PC based, check into the *Alladin* supervisor. This lets you call up in the middle of the night, check mail, read files, download libraries, and such. Much faster and far more conveniently than typing by hand.

Yes, *GEnie* is working on a few new graphical interfaces. But they still admittedly are ridiculously far behind on these.

As usual, I've gathered much of the resources I've mentioned into the *Names and Numbers* and *Switchmode Resources* sidebars. Check here first before calling our tech helpline.

Speaking of which, you can get tech help, consultant referrals, and off-the-wall networking by calling me at (602) 428-4073. Uh, your best calling times are weekdays, Mountain Standard Time.

Let's hear from you.❖

Don Lancaster's
Hardware Hacker

April, 1993

Every once in a while, a new hacker opportunity comes by that is absolutely stunning. An entire book crammed full of them is an even rarer event.

So, drop what you are doing right now and *run* out and grab yourself a copy of the new and free *Integrated Circuit Systems* data book.

These folks have just come out with an unbelievably mind blowing assortment of exciting new high-end hacker integrated circuits. Figure one gives you a quick summary of some of their more interesting products. Included are VGA to NTSC genlocks, 25 voice, CD quality synthesizers, 5 channel digitally controlled mixers, and SMPTE to MIDI time code chips.

Compared to these wonderments, their new fast battery charging chips and the unique new caller id devices seem hardly worth mentioning!

Oops. A major boo-boo. Back in the resistance wire story, I shudda said that 17.58 watts is a heating *rate* of one BTU *per minute*. Well over half of the "correction" letters I got on this were in themselves wrong.

Another good source for Nichrome substitutes is *Hoskins*. Their brand name is *Chromel*, and they are very big in alloys for higher temperature heater elements.

Piezoelectricity

Piezo stuff seems really great for hacking. But a lot of you helpline callers seem badly misinformed over what you can and cannot do piezo-wise. Let's take a closer look…

As figure two shows us, certain dielectric (or insulating) materials exhibit a *piezoelectric* effect. If you bend a piezo material, a charge can appear on its surface. Reversibly, if you apply an electrical charge to a piezo material, it should bend. Or at least try to bend, creating a force against whatever is restraining it. Thus, you can use a piezo material to convert mechanical forces or motions into electrical signals. Or vice versa.

The oldest classic piezo material is quartz. Which can be sliced up and plated for use in frequency standard crystals, filters, accellerometers, time delay lines, or force transducers.

A quartz crystal is just a rock. A highly mechanically resonant rock which has a few wires added to it. Depending on the application, the crystal will electrically appear as a very low impedance series resonant circuit. Or as a very high impedance *parallel* resonant circuit. Positive feedback externally applied around the quartz crystal might cause it to oscillate at its resonant frequency or at a chosen overtone. The frequency can end up very exact because of the temperature stability and very high Q of the mechanical system involved.

GSP500 –

A VGA to NTSC video genlocking processor. Allows VGA and super VGA text and graphic images to be displayed on standard NTSC televisions or recorded on a VCR. Also genlocks and synchronizes external camcorder or VCR inputs.

ICS1399 –

A music synthesizer for high performance professional keyboard instruments. Includes 25 voices and on-board real time digital filters and digital-to-analog conversion. Synthesis is by way of table lookup, so virtually any real or imagined instrument can be emulated.

ICS2101 –

A digitally controlled audio mixer that accepts five stereo input pairs and provides one stereo output pair. Log attenuation at half a decibel per step over a sixty decibel range. Optional panning mono mode. Intended for audio cards in multi-media personal computers.

ICS2008 –

A SMPTE Time Code receiver and generator. Offers both the older LTC longitudinal time code and the newer CITC vertical interval codes. These codes are often used in video editing and to synchronize multimedia events. Supports NTSC, PAL and film rates.

ICS2010 –

A MIDI compatible SMPTE time code processor. Allows you to use standard video time codes to control and sequence any MIDI music environment. Supports MIDI quarter frame messages. Selective video overlay is available as an option.

ICS1700 –

A "Quicksaver" controller for Nickel-Cadmium batteries. Does a full charge in twenty minutes. Uses a temperature sensing and rate of charge termination to determine a fast yet safe charging rate. Ideal for notebook computers and portable video applications.

ICS1660 –

A telephone caller id chip that includes ring detection and calling party number extraction. When provided by the phone company, the caller id signals appear between the first and second rings and are extracted by FSK modem techniques. Includes power down features.

Fig. 1 – EXCITING NEW HACKER CHIPS from the latest Integrated Circuit Systems data book. These will take years to sort out.
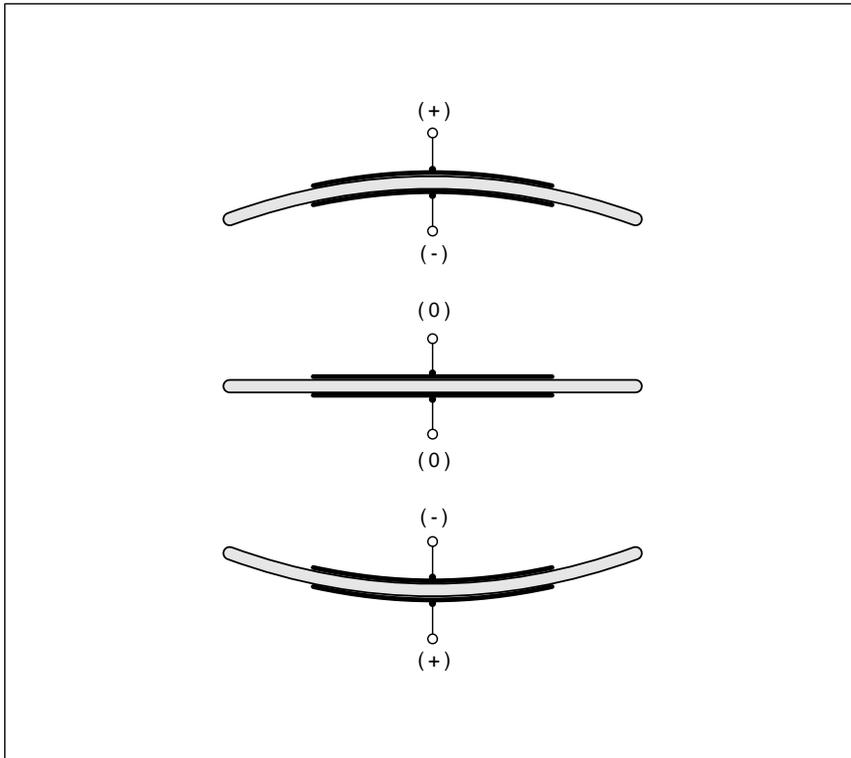
Fig. 2 – THE PIEZOELECTRIC EFFECT in certain dielectric materials converts an input voltage to a mechanical motion or vice versa. Important uses include filters, beepers, sonar, ultrasonics, micropositioners, gyros, microphones, miniature fans, strain gauges, and furnace ignitors.

We'll get further into crystals some other time. My favorite source for the lower frequency crystals is *Statek*, while *Crystek* is one of many places to go for small quantities of custom higher frequencies.

If at all possible, there are only *two* crystal frequencies which a hacker should select. These are the 32.768 kilohertz used in digital clocks, or the 3.579545 Megahertz used as the NTSC (Never the Same Color) subcarrier pilot. These two "magic" frequencies are ridiculously cheaper and easier to get than any other choice. Even if you have to divide or multiply to get what you really want, you'll usually end up far ahead by starting with these.

Another traditional piezo material was *Rochelle Salt*, otherwise known as potassium sodium tartrate. This material got used in "crystal" phono cartridges and "crystal" microphones. But Rochelle Salt was not all that stable or sensitive. You also had to chop up whole crystals, rather than forming it in the precise shape you really were after. Rochelle Salt has

largely been replaced by better and cheaper-to-process materials.

But you can buy Rochelle Salt at your drugstore (it is also a laxative) and can easily grow your own piezo materials. See *Crystals and Crystal Growing* in the Doubleday Science Series for more info.

One group of improved materials involve the technical ceramics such as barium titanate or the "PZT" lead zirconate titanate. These ceramics can be molded into pretty near any shape before firing. The resonant structures similar to quartz crystals get used as filters, especially for radio and tv intermediate frequency amplification stages. *Murata-Erie* is one leading supplier here.

Fancier piezo resonant structures can go by the name of *surface wave devices*. By carefully controlling the metal patterns on a piezo surface, you could launch and recover acoustical energy. The patterns can give you precise higher order filtering, time delays, or an equalization response. One big advantage of SAW devices

are that they are pre-tuned and need no adjustments. The important uses include cable tv, television if filters, cellular phones, and microwave apps. Ads for these show up in *Microwaves New Product Digest*.

Larger flat piezo *benders* resonate at audio frequencies and can form beepers or squawkers. You'll find a wide selection at *Radio Shack*, while a leading volume supplier is *Projects Unlimited*. Note that a bender does *not* oscillate by itself. It has to get used for feedback in a transistor or a logic inverter circuit. Some benders have taps provided to make their feedback easier. A pair of oscillators can get used to produce a series of beeps, instead of a continuous tone.

Physically smaller benders form ultrasonic microphones. These were once applied for ultrasonic Doppler burglar alarms before all those new pyroelectric "people detectors" blew them out of the water. And for remote controls before infrared diodes did them in. Ultrasonic mikes are still used for the electronic measuring devices used by contractors and rug installers. And to annoy dogs and mosquitoes. But, near as I can tell, though, all these really do is make the mosquitoes hungry.

Piezo devices in sheet or strip form could get used for hi-fi tweeters and higher quality, low cost electret-style "condenser" microphones. Unlike the traditional electrostatic mikes, no bias voltage supply is needed.

Larger size and higher power piezo transducers can be used for ultrasonic machining, cleaning, and for those underwater sonar aps. One source of ultrasonic cleaning transducers is *Branson*, while *EDO Acoustics* offers custom higher power piezo devices. Surplus sonar devices are sometimes provided by *Fair Radio Sales*. One leading sonar piezo manufacturer is *International Transducer*.

A sudden mechanical force applied to a stack of piezo elements creates a sparking barbeque lighter or a gas furnace striker. You can check your local hardware store for these.

A shorter and far more controlled stack makes a *piezo micropositioner*, a device that can precisely adjust things those micron sized distances required for microscopy, integrated circuit manufacturing, or for DNA

research. Surprisingly high forces are now available. One micropositioner source is *NEC*. Others advertise in the *Laser Focus World* and *Lasers and Optronics* trade journals.

Piezo fans have gotten built by resonating a pair of mylar blades. These can be an interesting way of handling low power spot cooling, but are unlikely to put the smallest dent in the muffin fan market. The main supplier is *Piezo Electric Products*. While some interesting piezo steppers and motors have been offered, these seem to be commercial failures.

Other emerging piezo uses include accellerometers, rate gyros, and for apps involving pressure transducers.

An exciting new variant of piezo material has now been developed by *Atochem/Pennwalt*. Ordinary *Kynar* plastic films are heated above their *Curie Point* and have a strong electric field applied. When cooled, this new electric field will get locked in, thus creating a piezo device known as an *electret*.

You will now find zillions of new applications for this thin, light, and ultra low cost Kynar piezo material. Including infrared people detectors (the films can be both piezoelectric and pyroelectric), driveway traffic detectors, bounceless pushbuttons, impact sensors, for electronic drums, shock detectors, handicapped aides, and bunches of others.

Those Atochem folks do have free sample piezo transducers available for you, along with instructions on how to assemble microphones, flame detectors, touch switches, and lots of other hacker stuff with them. Using nothing but business cards and foam coffee cups. They also offer a series of piezo development kits.

Tech info on piezo stuff tends to get spread a little thin. I know of no piezo industry trade journal, and the older *Piezoceramic Manufacturer's Association* appears to be long gone. There is a small *Ultrasonic Industry Manufacturer's Association*.

Some piezo material appears in the *IEEE Transactions on Sonics and Ultrasonics*. Also check the *Journal of the Acoustical Society of America*. And, of course, you can thoroughly and cheaply research *any* technical topic through the *Dialog Information Service*.

The problems

As I see it, there are two serious hacker misconceptions over piezo devices that seem to be causing a lot of helpline grief. These are the facts that *most piezo devices must be kept cool*, and that *most piezo devices are ac only and will not in any manner respond to continuous, steady state, or dc inputs*.

Any piezo device has a critical temperature called the *Curie Point*. Above the Curie Point temperature, *all piezo effects are lost*. And stay lost unless you go through a fancy and critical "recharging" process.

For most of the high volume, low cost materials, the Curie Point lies somewhat above the temperature of boiling water. You absolutely must keep both your ambient temperature and any internal heat buildup above ambient way under the Curie Point temperature at all times. For instance, using live steam near typical piezo devices is one big no-no. At least for the current crop of materials.

You must be extremely careful when you solder a piezo device to make certain you avoid reaching the Curie Point. Those ancient "crystal" phono cartridges were especially susceptable to soldering damage.

Yes, there are higher Curie Point piezo materials. But most of these are expensive and out of the mainstream. *Piezo Kinetics* is one innovator here.

In general, though, any time that you try to "push the envelope" of any device capabilities, something has to give. The chances are very good that raising your Curie Point will lead you to much higher materials cost, lower conversion efficiencies, and some matching/coupling problems. All of which will translate to more internal heat and poorer economics.

A piezo device is nothing but a capacitor that swaps charge back and forth. Figure three gives us a closer look at what really happens here. Say you apply a positive voltage. The device will bend when the voltage is

Fig. 3 – JUST LIKE ANY OTHER CAPACITOR, a piezo device obeys an "ac only" response. The only time you will get any energy transfer between electrical and mechanical inputs is when one or both are changing.

applied voltage or your mechanical force is changing. The steady state response is *zero*.

Just like any other capacitor.

Now let's look at it backward. Put a "perfect" voltmeter on your piezo device and push on the device. What happens? As soon as you press, there is a net surface charge which your voltmeter measures. As long as you are pushing, the voltmeter will *still* read the voltage resuting from this charge. But, *if there is any external or internal resistive load at all, the charge will rapidly drain off.*

Use a "real" voltmeter instead, and you will get a positive pulse when you first apply your pressure, and a negative pulse when you release it. Why? Because the resistance load inside the voltmeter drains off the previous charge.

Thus, piezo devices are inherently ac devices that only respond when the force, motion, or electrical signal is *changing.* There is no "dc", "constant voltage", or any "steady state" energy conversion response.

Many popular piezo devices have a natural time constant of one second or so. They can be used at sub-audio frequencies. But their dc steady state response is zero. Piezo devices are thus largely unsuited for such things as weigh scales, nav accellerometers, position transducers, or pressure to voltage converters. Unless you get really sneaky and use fancy chopper, carrier, or integrator stunts.

Piezo Power Generation?

Several helpline callers have asked whether piezo devices are suitable for commercial power generation. The possibilities look very grim here. By far the highest power piezo electricity generator I know about is the lighter for the carbide light on my caving helmet. Which is just a modified gas furnace igniter. And while the small wattage piezo fan motors do exist, they don't exactly have the entire air conditioning industry quaking in their boots.

Yes, there are higher power piezo transducers. Hundreds of watts for ultrasonic cleaners and machining. And perhaps thousands of watts for sonar. But I know of none of these ever *producing* electricity.

In fact, I would be very surprised if

PIEZO RESOURCES

Atochem/Pennwalt
3 Parkway
Philadelphia, PA 19102
(215) 587-7000

AVX Corporation
PO Box 867
Myrtle Beach, SC 29577
(803) 448-9411

Branson Ultrasonics
41 Eagle Road
Danbury, CT 06813
(203) 769-0400

Bruel & Kajer
185 Forest Street
Marlborough, MA 01752
(508) 481-7000

Channel Industries
839 Ward Drive
Santa Barbara, Ca 93111
(805) 967-0171

Channel Products
7100 Wilson Mills Road
Chesterland, OH 44026
(216) 423-0113

Crystek
2371 Crystal Drive
Fort Myers, FL 33906
(813) 936-2109

EDO Acoustics
2645 South 300 West
Salt Lake City, UT 84115
(801) 486-2115

Fair Radio Sales
PO Box 1105
Lima, OH 45802
(419) 227-6573

Int'l Transducer Corp
869 Ward Drive
Santa Barbara, CA 93111
(805) 683-2575

K-tech Corp
901 Pennsylvania Ave, NE
Albuquerque, NM 87110
(505) 268-3379

MG Electronics
32 Ranick Road
Hauppauge, NY 11788
(516) 582-3400

Motorola Ceramic Products
4800 Alameda blvd, NE
Albuquerque, NM 87113
(505) 822-8801

Murata-Erie
2200 Lake Park Drive
Smyrna, GA 30080
(404) 436-1300

NEC
PO Box 7241
Mountain View, CA 94039
(800) 632-3531

Piezo Electric Products
212 Durham Avenue
Metuchen, NJ 08840
(908) 548-2800

Piezo Kinetics
PO Box 756
Bellefonte, PA 16823
(814) 355-1593

Projects Unlimited
3680 Wyse Road
Dayton, OH 45414
(513) 890-1918

Shogyo
287 Northern Blvd
Great Neck, NY 11021
(516) 466-0911

Statek
512 N Main Street
Orange, CA 92668
(714) 639-7810

Ultrasonic Industry Association
PO Box 5126
Old Bridge, NJ 08857
(201) 679-9666

Valpey-Fisher Corp
75 South Street
Hopkinton, MA 01748
(508) 435-6831

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applied and unbend afterward. There will be no current before the voltage is applied. There will be a *positive* current *only while your bending is taking place.* The energy goes into the physical motion work load and raising the internal charge state of the piezo device. After your bending is finished, you'll still need to apply a voltage to *keep* the device bent, but there will be *zero* current, either into or out of the device.

When you remove the voltage, the device returns to its flat state. This time there should be a net *negative* current *out* of the device as the higher internal energy state gets released. Some of this negative energy may get spent overcoming any air resistance, producing internal heating, or doing other mechanical work.

At any rate, our key point here is *there is only a net energy flow into or out of a piezo device whenever the*

there *ever* was *any* piezo device to date which generated more recovered electrical power than was used in its construction.

Many new piezo aps seem stuck under a two watt limit. Recent fans, positioners, and stepper motors above this size have been non-competitive with traditional solutions.

Commercial power recovery would require devices hundreds or even thousands of times larger than the two watt limit. Once again, whenever you push the envelope, something has to got to give.

For piezo power generation, the mechanical work input would have to be oscillatory and usually has to be resonantly coupled. *Ya gotta shake the transducer, not simply push on it*! Piezo devices also must be kept cool. If they get anywhere near their *Curie Point*, all piezo effects stop.

Worse yet, the best efficiencies of the high power units are often fifty percent or less. Leading to very bad economics and internal heating.

Worst of all, most piezo elements are inherently very high impedance devices. Usually in the ten megohm range. For maximum power transfer out of any system, the impedances of your source and load *must* be made equal. This means you'll usually get a high voltage, higher frequency, high impedance output from any piezo device. Tens of kilovolts or higher for larger devices. Efficiently converting this into recoverable power is not a trivial task.

Several of the ap notes drive home how dramatically piezo output power drops if you try to drive too low a resistance load. From watts down to milliwatts even.

It's also not at all obvious to me how you can efficiently and cheaply combine the multiple outputs from several piezo devices.

Finally, unless you are in an "Uh, compared to what?" situation in outer space or on a desert island, the first and foremost question in any power generation scheme is "What are the economics?" If the rate of the energy production cannot more than pay for the time value of the money used in construction, then your conversion scheme is totally useless.

Infinite cost breakeven times are trivially easy to pick up. All that has

WARNING: Extreme shock hazard!
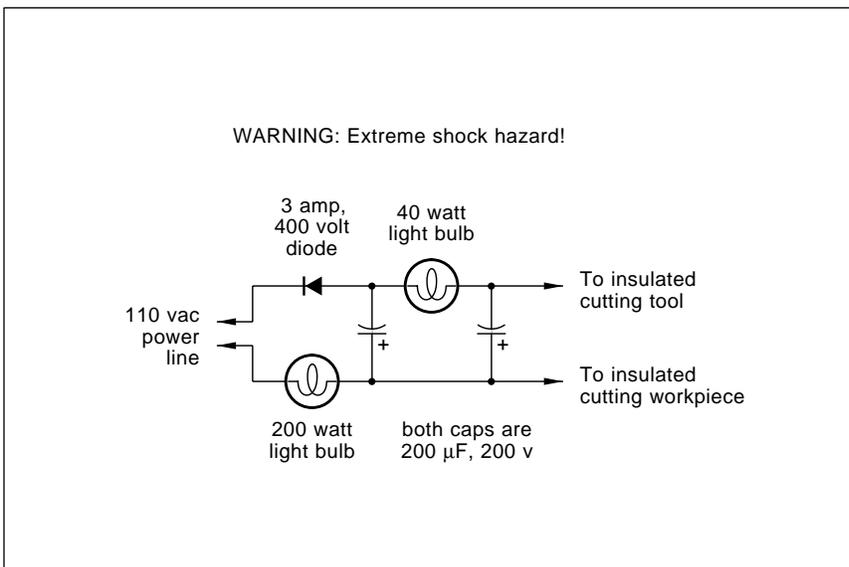
Fig. 4 – AN ULTRA-SIMPLE EDM LASHUP. The lamps act as dynamic regulators, with the smaller one setting your sparking rate Be certain to keep the tool and workpiece insulated from ground at all times. A dielectric fluid must be used. Kerosine is possible but not recommended.

to happen is that the interest on the time value of the construction money exceed the value to date of the generated power.

Viable alternatives to piezo power generation are covered in depth in *Electric Power Research Institute* and the *Association of Energy Engineers* publications.

The bottom line: There are all sorts of incredible hardware hacking apps which use piezoelectricity. Especially with all those new Kynar films. But commercial power generation does not seem to be one of them.

Piezo resources

I've gathered some of places to go for more piezo info into our resource sidebar. Most of the sources shown but not covered above are suppliers of materials and devices.

For this month's contest, either (A) tell me about a piezo trade journal, or (B) show me any new and hacker friendly piezo ap that does not violate the "no dc response" and "low temp only" rules. There will be all of my *Incredible Secret Money Machine II* book prizes, plus an all expense paid *tinaja quest* (FOB Thatcher, AZ) for two going to the very best of all.

As usual, send your entries directly to me here at *Synergetics* and not to **Electronics Now** editorial.

More on EDM machining

Warning: What follows can involve severe shock and fire hazards. Do not try this trick at home unless you know exactly what you are getting into!

But this one seems far too cute to ignore. Awesome, even.

I've had a lot of helpline requests for more details on the EDM electric discharge machining we looked at two columns back. It turns out a very cheap, stunningly elegant, and ultra simple scheme for EDM machining first appeared in the March 1968 issue of *Popular Science* and later on got reworked in the January 1991 issue of *Home Shop Machinist*. Their circuit appears in figure four.

All you have is a half wave dc power supply driving a relaxation oscillator, with the *insulated* tool being negative and the *insulated* work being positive. Any old three amp, 400 volt power diode from *Radio Shack* could get used as the rectifier. Fresh and very high quality electrolytics are recommended. 200 volts minimum. Older or very cheap ones could possibly explode in this circuit. A "bomb shelter" type of case is recommended.

The light bulbs have much lower resistances when they are cold than hot. These sneakily act as dynamic

regulators to limit the current should your tool get stuck. This is elegant simplicity at its best. The size of the smaller lamp sets your cutting rate.

Both the tool and the workpiece must be fully and totally insulated from ground! If you want to ground your workpiece (a darn good idea), a large isolation transformer *must* be added to your ac input.

While you might employ plain old kerosine as a dielectric cutting fluid, it is highly flammable. Not remotely as nasty as gasoline, but very much a fire hazard just the same. I would instead recommend using the "real" water based dielectric resins we saw back in the EDM survey. You'll have the best luck with a drill press or a mill that has a slow controllable rate vertical power feed.

The most obvious use is to remove broken taps or stuck drills. Be sure to remember that a continuous flow of dielectric fluid between the tool and work must be maintained at all times.

A reminder that *EDM Today* is the leading trade journal here, and your foremost place to check for ads on machines, materials, and supplies.

New tech lit

From *Teltone*, their new *Design Solutions* data book on tone receivers, call progress detector ics, and phone signalling devices. Along with some good ap notes. From *Unitrode*, a new *Linear Circuits Handbook*. Mostly on drivers, power supply circuits, and battery charger chips.

Randy Fromm's Big Blue Book of Really Great Technical Information tells you bunches about commercial video game repair. In a readable and well organized format. Randy also offers videos on video monitors and on game repairs and refurbishment.

He has lots of insider tricks that can quickly and cheaply solve typical repair problems.

I am amazed at how klutzy and primitive many video games still are. Most of these are still foot square circuit boards crammed with jelly bean TTL or CMOS chips. Thus, they fail often but are easy to fix. I guess that the desire to retrofit previous machines has pretty much kept the older technology in place.

Speaking of video games, *MCM Electronics* offers $8 bit drivers that let you remove the tamperproof *Sega* or *Nintendo* game cartridges.

If you are about to come unglued, check out *Elsworth Adhesives*. They do seem to stock just about all major epoxies, hot melts, cyanoacrylates, silicones, and such from nearly all of the major suppliers.

The price of laser pointers is still in free fall. The cheapest this week is the $72 model from *Alpec*. Range is 55 yards or so.

Note that you can't just connect a visible laser to a battery. Careful and tight current regulation is needed to prevent the fragile die from literally blowing itself off its mounting.

Normally, an internal photodiode is used in a feedback loop. I'll try to work up more details on this in a future column.

Our two unusual magazines for this month are *Amusment Business* and the *Carnivorous Plant Newsletter*.

The former is where you go to rent the Batmobile, buy a steam calliope, see how much your favorite rock star is making on their concerts, or find job ads so you can run away and join the circus. The latter is for veggies that go chomp in the night.

A reminder here that I have got autographed copies of my revised *Incredible Secret Money Machine II* here for you at my own *Synergetics*. This book is a must if you are starting up your own tech venture. Plus a reminders about my Hadware Hacker RoundTable on *GEnie* PSRT at (800) 638-9636. And our no charge voice tech hepline can be reached via (602) 428-4073. Best calling times are 8-5 weekdays, Mountain Standard time.

Most of those items I've mentioned do appear in our *Names & Numbers* or *Piezo Resources* sidebars. Be sure to check here first before calling our helpline. Let's hear from you.❖

Don Lancaster's
Hardware Hacker

May, 1993

Electronics cannot stand on its own. It has to build upon all the underlying foundations of math, physics, chemistry, and the other engineering disciplines.

This month, I figured I'd take a back-to-the-basics tack over a topic that has been causing more than its share of helpline grief lately.

In short, we are long past overdue in taking a close look at the…

Fundamentals of thermodynamics

As our figure one shows us, a *heat engine* is some device or scheme that accepts thermal energy at a high input source temperature T_H, outputs some useful mechanical work, and finally rejects remaining thermal energy to a lower output sink temperature T_L.

Nearly all auto and airplane power sources use heat engines, as do most electrical generators. Variations on the heat engine theme lead us to heat pumps, icemakers, vacuum systems, refrigerators, and compressors.

And, for that matter, to life itself.

The study of heat engines is known as *thermodynamics*. While more of a mechanical engineering topic than an electrical one, (A) EE students have to take at least one thermo course; (B) nearly all modern heat engines need lots of support electronics; (C) many home power and new energy recovery schemes are actually heat engines in disguise; and (D) knowing the thermo fundamentals lets you instantly sort out the perpetual motion ripoffs and the outrageous pipe dreams from the realities of practical physics and real world economics.

We should note up front that more people have spent more time hacking heat engine ideas than on *any* other engineering topic. The field has been studied to death, and there are *tons* of readily available literature out there waiting for your immediate access.

Unless you can bring something genuinely, truly, and astonishingly new to the table, the chances are your "new" heat engine concept has gotten thoroughly trashed over decades ago. Or even centuries before.

Ferinstance, I got this model heat engine in the mail. It was a clever demo of how crucially important the *reversibility* problem is in preventing you from getting useful economics. Reversibility is a very sticky thermo problem which was first solved in a brilliant breakthrough analysis first done by James Watt. In 1784.

Thermo laws

Any study of thermo starts off with the laws of thermodynamics. While unproven, nobody has *ever* been able to find *any* exception to these laws. At least not on an everyday scale.

Countless individuals have blown incredible amounts of their time and money trying to crack these thermo laws. All of them have failed totally.

Without exception.

The laws are pretty fundamental, and range well beyond heat engines. For instance, cell biology, the very life process itself, photosynthesis, the chemical reactions, and much of solar power all must obey these laws.

Glibly parapharased, the laws are (A) You cannot win; (B) You cannot break even: and (C) Sure, the dice are crooked, but this is the only game in town.

Uh, more formally: Left to its own devices, heat energy always travels from higher temperatures to lower ones. Systems always tend to their most chaotic and lowest energy level states. Energy can neither be created nor destroyed in any thermodynamic process.

If you do build a heat engine, *only a small fraction of the total energy can ever be recovered as useful work; all the rest is irretrievably lost as low grade heat.*

Ah yes, that fraction. How big and just how much? Enter one of the most brilliant hardware hackers of all time by the name of Sadi Carnot. As most hardware hackers, Carnot did not have the foggiest idea what he was really doing. It took "them" decades to finally understand how utterly profound and fundamental Carnot's discovery was.

Typical heat engines use a *working fluid*. More important heat engine fluids include air, steam, ammonia, freon, mercury, nitrogen, hydrogen, helium, or even liquid sodium. The working fluid goes through a number of individual steps or *processes* to trace out a *cycle*. Obviously, a heat engine cycle must close upon itself and return to initial conditions such that useful work can continue.

These thermodynamic cycles can usually be graphed in your choice of a *pressure-volume (p-v)* diagram or a *temperature-entropy (t-s)* diagram.

The *area* inside the cycle on either a p-v or t-s diagram is related to how
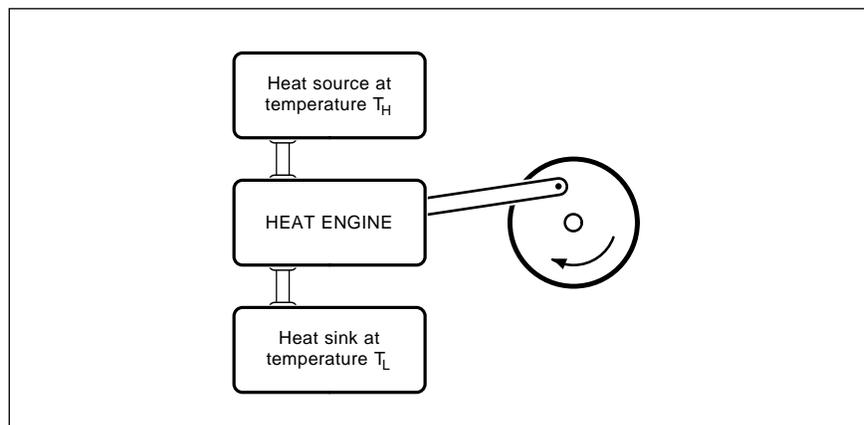
Fig. 1 – A HEAT ENGINE accepts energy from a high temperature source, does useful mechanical work, and then will reject a portion of that energy to a lower temperature sink. Only a fraction of the energy can be converted.

As one process in a heat engine cycle, assume you have a fluid you wish to compress by adding weight to the piston such that your piston drops by exactly one foot...

On your first try, you throw an eight pound brick on the piston and note that the piston does in fact drop by one foot. You have done 8.0 foot pounds of work. As we will shortly see, this is a useless and **BADLY IRREVERSIBLE** process, because one-half of your work will get lost as irrecoverable low grade heat...

On your second try, you place a one pound rock on the piston, wait till things settle, and then add another one pound rock. You will still need eight pounds of rocks, but this time, the work needed is only 8/8 + 7/8 + 6/8 + 5/8 + 4/8 + 3/8 + 2/8 + 1/8 = 4.5 foot pounds of work. This is a useful but **MODERATELY IRREVERSIBLE** process in which one-eighth of your work gets thrown away...

On your third try, you place a feather on the piston, wait till things settle, and add another feather. You still need eight pounds of feathers, but this time the work needed is only the tiniest amount above 4 foot pounds. This is a **FULLY REVERSIBLE** process in which virtually none of your work gets thrown away...

Any fully reversible scheme to compress or expand a fluid is also called an **ADIABATIC** process. Heat is neither added nor removed in any reversible adiabatic process.

Fig. 2 – EFFICIENT HEAT ENGINES demand that all the processes used be fully reversible. Here are some good and bad examples.

much useful work you can extract from your heat engine. The *efficiency* of any engine is the ratio of the useful work you extract compared against the energy which you must dump as low grade heat.

Numerous heat engine cycles have been dreamt up. The *Otto* cycle gets used in gasoline engines, while the *Diesel* cycle obviously gets used in diesel power plants. Electric power turbines use a *Rankin* cycle. Or some multi-stage improvement thereon. A lot of alternate energy people get real excited over a *Stirling* cycle, since it is an "external combustion" type of engine which can accept heat from diverse or low grade sources.

Every few years or so, somebody reinvents the old Stirling engine, and then builds a bunch of prototypes that just barely miss. Then they will just barely go bankrupt. To date, the old Stirling cycle has largely proven to be both a sucker bet and an economic rathole. Except possibly for arcane cryogenic cooling aps.

What Carnot did was ask "What is the finest theoretical thermodynamic cycle you could possibly create?" and "What are the efficiency limits to the finest possible cycle?"

It was obvious that each part of a Carnot cycle had to be lossless. More precisely, all the processes involved had to be *reversible*. You have to be able to undo anything you just did without losing any heat to friction or other losses. This means "no sudden moves" and "no rapid changes", with everything altering as incrementally and as slowly as possible. It will also mean zero friction, lossless seals, and perfect insulation.

Figure two shows you more on the concept of reversibility.

Ferinstance, say you want to use a piston to compress the gas inside a non-insulated cylinder. Some work is needed to get your gas reduced to a required size. Any work above that is lost as low grade heat.

Say you build up your cylinder and throw an eight pound weight on it.

You note that this particular piston happens to drop by a foot, doing work to compress your gas. In this case, eight foot pounds of work were used, since the eight pound weight dropped by one foot.

Is this the best you can do? Say instead, you put a one pound weight on, waited till things settled down, added another one pound weight, and so on. You now have the first pound going a full foot and the final pound only going an eighth of a foot. Your total work is 8/8 + 7/8 + 6/8 + 5/8 + 4/8 + 3/8 + 2/8 + 1/8 = 4.5 foot pounds of total work input.

Yet, in each case, you compressed the gas by the same amount, raising its energy state by the same value. The extra 3.5 foot pounds of work has dropped through that irrecoverable low grade heat rathole.

In both examples, you do have an irreversible process. But your second one is clearly much better. As a third try, put a feather on the piston. Wait till things settle, and then put another feather on the piston. Repeat this for eight pounds of feathers, and you will also end up with the gas compressed by a foot. And only 4.0 foot pounds of total work will be needed. This is a reversible process and the best you can do. And twice as efficient as your first attempt.

One more time: Ya gotta be able to undo what you just did. At all times, you do have to be willing and able to stuff the Genie *back* into the bottle.

That's what reversibility is all about.

There are several rather important reversible processes. One of these is called an *isothermal* process, where everything takes place at a constant temperature. The heat energy receiver has to be at a temperature only a tad lower than the energy source. And the heat source has to be so large that taking a small amount of energy out of it does not significantly change its temperature.

A second is an *adiabatic* process, in which heat energy is neither added nor removed. *For a full reversibility, any compression or expansion of a working fluid should be adiabatic.*

At any rate, the Carnot cycle uses fully reversible processes to trace out the best possible of theoretically ideal heat engine cycles.

Figure three shows you some more Carnot cycle details. Once again, this one is the best possible one you can ever build. Why? Because of the full reversibility. You just can't get better than this. If you think otherwise, you are flat out wrong. Guaranteed.

In the Carnot cycle, you start with a working fluid at a low temperature. Then you adiabatically compress that gas by doing work on it. Typically, the new external energy required can come from a flywheel or a second cylinder in the engine. Compressing the fluid raises its temperature and reduces its volume. *Extreme care is needed to neither add nor remove any heat energy during compression.* The temperature rise has to result solely from the volume reduction itself.

Compression will continue until a temperature very slightly under that of the heat source is reached.

After compression, an isothermal process transfers hot heat energy into the fluid, expanding it and increasing the pressure. The temperature, of course, stays the same. In the third step, your gas adiabatically expands while delivering useful output work.

The fluid volume goes up and the temperature goes down.

A final isothermal process dumps the remaining heat energy to the low end heat sink, reducing the volume and closing the cycle.

Once again, that *area* inside the curve on the p-v diagram determines how much work gets delivered.

Since every process is reversible,

you can input high temperature heat energy to produce output mechanical work. Or, you can input mechanical work to pump heat from the low side to the high side.

A gas engine runs "frontwards". A refrigerator runs "backwards". And a heat pump can either heat or cool, by swapping the high side and low side destinations.

When you go through the math (the derivation takes a full lecture hour in any university physics course), this stunningly elegant and simple result pops out…

$$\eta = (T_H - T_L)/T_H$$

Restated in English: *The very best possible efficiency you could ever get out of any heat engine is determined solely by the ratio of your source temperature to the sink temperature.*

No matter what the cycle, fluid, or the engineering used!

And our key point: To get useful work out of any heat engine, you'll have to throw lots more energy away

as irrecoverable low grade heat.

As an example, a modern auto engine has a theoretical efficiency of 55 percent, with something like 38 percent being a typical real world value. That is at the flywheel. The actual efficiency as a transportation system is far lower.

Oh yeah. One minor gotcha. You have to use absolute temperatures for the Carnot formula to work. Absolute degrees Rankin are 460 degrees above Farenheit. Absolute degrees Kelvin are 273 degrees above Centigrade.

And any percentage efficiency is a hundred times the efficiency stated as a fraction from 0.0 to 1.0.

Let's try out the formula ourselves. On down my street is an impressive artesian hot well that's spewing forth mightily at 125 degrees F. Could we get some electricity out of it?

Assume the local average ground temperature is 75 degrees (The well sits in the Upper Sonoran life zone.) Your best possible energy recovery efficiency here would be…

The **AREA** inside the Carnot cycle determines how much useful mechanical work is output.

The **EFFICIENCY** of a Carnot cycle is determined solely by this elegantly simple formula:

$$\eta = (T_H - T_L)/T_H = \Delta T/T_H$$

You can multiply this 0-1 value by 100 to get the percentage efficiency. Note that an **ABSOLUTE** temperature scale must be used such as Kelvin (Centigrade + 270) or Rankin (Farenheit + 460).

Note that the best possible efficiency of any heat engine depends **ONLY** upon the highside/lowside temperature differential and nothing else!

Fig. 3 – THE MOST EFFICIENT HEAT ENGINE you can possibly build is called a Carnot Cycle. All four processes are fully reversible. Even the best Carnot cycles MUST dump a lot of irrecoverable energy as low grade heat.

$$((125 + 460) - (75 + 460))/ (125 + 460) = .085$$

Or a mere 8.5 percent, under ideal conditions. That's assuming a perfect Carnot cycle. In the real world, you'd be lucky to get a tiny fraction of that. Say three percent net. Thus, for every kilowatt hour you generate, you have to throw *thirty-two* of them away!

Sadly, it does make perfectly good sense to ignore some $20,000 worth of electricity a year just by dumping it into the Gila River. Why? Because any real-world recovery project of this size and temperature differential could *never* pay for the engineering, materials, operating costs, flood zone risks, and the time value of money needed to properly do the job.

Is there any way you can beat the thermo laws? Generating electricity won't hack it, since you can always use your electricity to run a motor, which instantly gets you back to a heat engine.

You can switch to a *binary* or even a *trinary* cycle which uses multiple stages and different fluids. But these often will only marginally improve the efficiency while doubling costs.

The only other way I know of is to do something useful with the rejected low grade heat. Say by heating water, equalizing process temperatures, or starting your own catfish farm.

A solar panel that also heats water should have much better economics than one that solely generates some electricity. Schemes such as these are sometimes called *cogeneration* and they are now a very hot topic indeed. There is even a *World Cogeneration* trade journal.

A reality check

So, how do you separate the "real" heat engines from the scams and the wishful thinking daydreams? First, calculate your Carnot efficiency and see what this reveals about the claims involved. Be especially suspect of "this is not a heat engine," or "the thermodynamic laws do not apply to me" evasions.

Then carefully look at the *p-v* or *t-s* diagrams (these will *always* be very obvious on any legit device). Then check carefully for anything which is obviously non-reversible.

Any sudden changes or purposely adding coolant to close a cycle are dead giveaways that all is not well.

Always ask "Can each and every process step in use be run backwards just as well as forwards?"

Then you throw in some economic analysis. Most crucially your time to breakeven. This is the length of time which is needed for your generated power to pay for the materials, the design, and time value of the money needed to create the device. Assume that 17.58 watts is a heating rate of one BTU per minute, and raises one pound of water by one degree F. And that a nickel per kilowatt-hour is a workable ballpark avoided cost for electricity. And that a gallon of water weighs eight pounds. And that the time value of money normally triples the cost of a project.

Note that the time to breakeven can easily be infinite! If you produce less electrical revenue per year than the interest on the construction financing is costing you, the longer you run, the
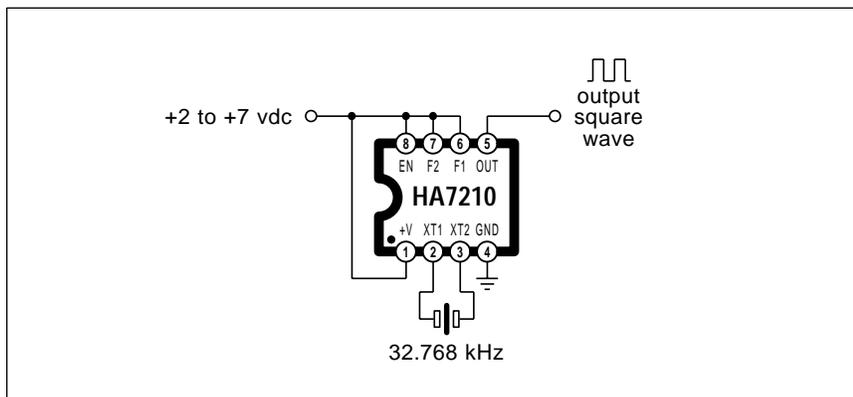
Fig. 4 – MICROPOWER CRYSTAL OSCILLATOR by Harris Semiconductor only needs five microamps of supply current from a source as low as two volts. It costs under a dollar. Free sample kits are available.

more you will lose.

Finally, be extremely wary of the word "Stirling". When and where it happens to occur.

My favorite popular thermo book is *Heat Engines* by Sanford and found in the Doubleday Science Series.

Beyond this one, pick up any of the dozens of college level course texts. Important thermo resources include the *SAE Library* from the *Society of Automotive Engineers*, and the *EPRI Publications* from the *Electric Power Research Institute*.

Of the many trade journals, *Power Engineering* is typical; it targets large scale electrical generation. And, of course, virtually any and all thermo papers ever published are instantly available through *Dialog*.

Communications resources

Where can you go to get a crystal for a pager? Or to find out more on fiber optic comm? Or information on wireless modems? Or phone testing? Or computer local area networks?

As always, your first and foremost source of insider information in any field is in the trade journals.

As our resource sidebar for this month, I have gathered together a bunch of the more obscure and more fragmented communications trade journals for you.

I have a hunch I may have missed a few here, so be sure to let me know if you have any other favorites. A free ISMM II for your trouble.

A micropower crystal oscillator

Hacking a crystal oscillator is no big deal these days. You just bias any old CMOS gate into its active region and hang a crystal in the feedback path. But things get tricky fast if you try to run at ultra low supply currents or want to reliably start at unusually low voltages.

Most hackers have discovered that your typical grunt CMOS transistors run out of gain at ultra low currents. And ultimately found out that the best route to micropower oscillators was to use bipolar transistors instead of CMOS gates.

Harris Semiconductor has newly introduced a cheap and very simple HA7210 all-CMOS crystal oscillator chip. It costs under a dollar and free samples are available. As figure four

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NAMES AND NUMBERS

Dialog
3460 Hillview Avenue
Palo Alto, CA 94304
(415) 858-2700

Electric Power Research Inst.
PO Box 10412
Palo Alto, CA 94303
(415) 855-2000

GEnie
401 N Washington Street
Rockville, MD 20850
(800) 638-9636

Grass Valley Group
PO Box 1114
Grass Valley, CA 95945
(916) 478-3000

Harris Semiconductor
1301 Woody Burke Rd CB 1-25
Melbourne, FL 32902
(407) 724-3739

Hitachi
2000 Sierra Point Parkway
Brisbane, CA 94005
(415) 589-8300

Industrial Laser Review
One Technology Park Drive
Westford, MA 01886
(508) 692-0700

Navtech Books & Software
2775 S Quincy Street, Ste 610
Arlington, VA 22206
(800) NAV-0885

Power Engineering
1250 S Grove Avenue, Ste 302
Barrington, IL 60010
(708) 382-2450

Ragtime
4218 Jessup
Ceres, CA 95307
(209) 668-0366

Resource Central
PO Box 11250
Overland Park, KS 66207
(913) 649-0567

Silicon Systems
14351 Myford Road
Tustin, CA 92680
(714) 573-6000

Society Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096
(412) 776-4841

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

Rolf K. Taylor
RFD #1 Keeler Lane
North Salem, NY 10560
(914) 669-5421

Trident Microsystems
205 Ravendale Drive
Mountain View, CA 94043
(415) 691-9211

Voltek
100 Shepard Street
Lawrence, MA 01843
(508) 685-2557

World Cogeneration
PO Box 1589
Dallas, TX 75221
(214) 691-3911

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shows us, you simply hang a crystal on the chip, and away you go. The current is a mere five microamps at 32 kilohertz.

Pin six is an enable. Keep it high to run. Make it low to disable the chip. Pins seven and eight can program the operating current. Make them both high for low frequencies (10-100 kHz) and both low for high frequencies (5-10 MHz). Supply voltage range is 2.0 to 7.0 volts.

New tech lit

Some new integrated circuits for this month: The SSI 67F687 is a new engine interface peripheral offered by *Silicon Systems*. It receives gasoline engine crank and cam inputs for use as timing and pollution management.

From *Trident*, a new *Video View* video processing chip set that offers scalable, full motion video windows

and frame capture to VGA systems.

From *Hitachi*, the new HD49049FS picture-in-picture controller chip also intended for video insertion aps.

The *Grass Valley Group* has a fine video *Dictionary of Technical Terms* newly available.

A good bookstore for navigation texts and GPS satellite secrets is the *Navitech Book & Software Store*.

One source for Apple II repairs and supplies is *Rolf Taylor*.

The best Apple II magazine is still *Resource Central*. And the *A2 GEnie* RoundTable has just seen its 20,000th library upload.

Yet another trade journal for this month is the *Industrial Laser Review*.

Free samples of *Volara*, *Volextra*, and *Minicel* foams are available from *Voltek*. Ask for their specifier kit.

A good source for steam calliopes is *Ragtime*. They offer a $5 catalog. ❖

Don Lancaster's
Hardware Hacker

Short haul telemetry
Max-min slope theory
SETI books & resources
Unique new optical link
Maximum power transfers

June, 1993

As I might have mentioned a time or two before, I am the sysop of *GEnie* PSRT and do have bunches of reprints of my *Hardware Hacker*, *Ask the Guru*, *Blatant Opportunist*, *Resource Bin* and *LaserWriter Corner* columns.

And hundreds of files on hacking, PostScript, and my Book-on-demand publishing. Typical file downloading costs are around twenty one cents.

I've just made an arrangement with *GEnie* to provide you with a new fast modem access startup. Just autodial (800) 638-8369 and then type HHH. When prompted, enter your top secret access code of XTX99005,SCRIPT.

Whatever you do, keep this secret password carefully hidden and do not reveal it to anyone else.

GEnie has many thousands of local access lines across the country. But if you live in a really remote area, they now offer a brand new (800) number service. They've also improved their Mac graphic interface.

We might start off with a pair of back-to-the-basics fundamentals…

Maximum power transfer

Say you're using an electrical or electronic generator. Say further it happens to provide a one ohm source impedance and is outputting a one volt signal. What is your "best" load resistance?

As figure one shows us, there is no "best" choice. Only compromises that depend entirely on exactly what you are trying to do.

If you make your load resistance fairly high, you'll get high efficiency and good regulation. *But you will be unable to get the maximum possible power from your generator.* Your ac power utility is an example where the generator impedance is made as low as possible to minimize all the source and transmission losses.

If you make your load resistance *equal* to your source resistance, you should extract the maximum possible power from your generator. But the efficiency will be a mere *fifty* percent and your regulation will be poor.

Video and rf transmission lines get important areas where you want to precisely match load to the source. Besides delivering maximum power, you'll also minimize reflections and standing waves. Other areas where "make load = source" are important are the older power audio amplifiers driving speakers, car batteries when cold cranking, and solar cells trying to deliver as much power to the load as possible.

You also have the choice of using a very low load resistance. Which will

(A) Typical generator and normalized load. Varying load resistor R changes the total delivered power…
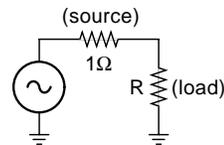
(source)
1Ω
R (load)

(B) Maximum power transfer takes place whenever the source resistance matches the load resistance…

efficiency
load power
source power
LOAD RESISTANCE IN OHMS
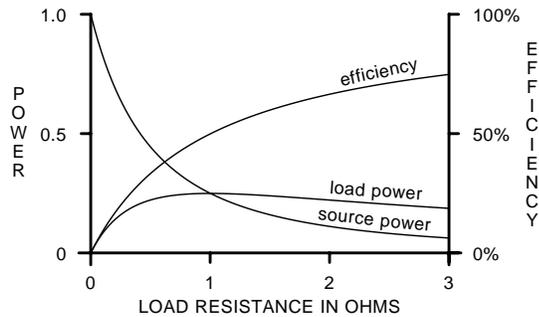
(C) How to prove the maximum power transfer theorem…

Borrow these two rules from differential calculus…

$$d(uv) = vdu + udv$$

$$d(u^n du) = nu^{n-1} du$$

The voltage across the load will be…

$$V_L = R/(1 + R)$$

The load power E^2/R will simplify to…

$$P_L = R/(1 + R)^2$$

Take the derivative and set it equal to zero…

$$(1 + R)^{-2} - 2(1 + R)^{-3} = 0$$

And simplify to…

$$(1 + R) - 2 = 0$$

Which solves as R = 1.

Fig. 1 – THE MAXIMUM POWER TRANSFORM THEOREM tells us that you deliver the most possible power to a load only when you purposely burn up half of the generated power in your source. Here are some key details.

At a local **MAXIMUM**, the slope (or the first derivative) will be **ZERO** and the rate-of-change of slope (or the second derivative) will be **NEGATIVE**…

At a local **MINIMUM**, the slope (or the first derivative) will be **ZERO** and the rate-of-change of slope (or the second derivative) will now be **POSITIVE**…

At an **INFLECTION POINT**, the slope (or the first derivative) will be **ZERO** and the rate-of-change of slope (or the second derivative) will also be **ZERO**…

Fig. 2 – MAX-MIN THEORY is a branch of differential calculus that lets you quickly and easily find a maximum or a minimum of any reasonable curve.

give you a horrible efficiency and a terrible regulation. It also will only deliver a tiny fraction of the possible generator power. But there are a very few lower level uses where you want your generator to look and act like a *current source*.

For instance, a current source load for a transistor amplifier can offer an enormously high voltage gain. These unusual apps sometimes justify the low power and bad efficiency.

Do note what this maximum power transfer curve is telling us: *You can deliver the most power to a load by throwing half of the generated power away in your source!*

The max power transfer curve is surprisingly broad. Double or halve your load and your power that gets delivered only drops by about twelve percent or so. Thus, an exact match sometimes isn't all that important for maximum power transfer. A precise match just might be needed for other reasons, though. Such as to eliminate standing waves and reflections.

If you are going to mismatch, it usually pays to do so on the high side. This way your overall efficiency will be better, even if the delivered power drops a tad.

Let's look at several examples of how a bad source-to-load mismatch can severely do you in. In figure two, let's take a piezo striker and see what we can get out of it. Let's assume the striker has a source impedance of ten megohms and outputs a peak of 1600 volts. We will also disable the spark

gap to prevent breakdown.

Into an open circuit, we get *zero* power. For maximum possible power, we'll use a ten meg load, matching source to load. Half the voltage will appear across the load, and our power will end up as 640 milliwatts. Per the usual $P = E^2/R$ rule.

Which is over half a watt, so we should be able to light a lamp with it, right? Wrong. As 2-B shows us, a flashlight bulb offers a resistance of about ten ohms. With a ten ohm load and a ten meg source, you can only deliver 256 *nano*watts!

Your efficiency is essentially *zero*. Ergo, no light.

Can you do better? Substituting a neon lamp for a flashlight bulb would help bunches. Instead, you can place a transformer with a 1000:1 turns ratio between the striker and the bulb, as shown in 2-C. A 1000:1 turns ratio gives you a 1,000,000:1 impedance ratio. Your bulb now "looks" like a ten meg load to the source. And you should get nearly the full maximum power flashing the lamp.

Remember, of course, that all piezo devices are ac only generators.

Most small impedance mismatches between source and load are not that big a deal. But bad ones (especially with high value sources driving low value loads) will severely do you in.

Several columns back, we found several good reasons why any piezo power production hacks were likely to end up a bad scene. Some of you helpline callers pointed out there is

an even more fundamental gotcha.

Most power generators are either *E-field machines* or *H-field machines*. An H-field machine uses a changing *magnetic field* to induce *current* into a *conductor*. An E-field machine will use a changing *electric field* to induce a *voltage* across an *insulator*.

All E-field machines are inherently high impedance devices. *The power density of all known E-field machines is extremely low*. E-field machines tend to force you to the inefficient extreme left of the maximum power transfer curve of figure one. Precisely where you don't wanna be.

The curent state of the art in both materials science and high vacuum techniques simply will not allow us to construct any economical high power E-field machine.

As far as I know, there *never* has been *any* E-field machine anywhere *ever* produce commercial "nickel per kilowatt-hour" ac power. I'll give you an *Incredible Secret Money Machine* if you can prove me wrong on this.

And while any piezo generator is obviously an E-field machine, it is only a "fair to middlin" one at its very best. Sigh…

Finding maximums and minimums

There's a number of fairly obvious ways you could verify that maximum power transfer curve of figure one. Being lazy, I just told the incredibly superb general purpose PostScript computer language to plot it for me. The short and simple figure one code appears in HACK65.PS on my *GEnie* PSRT RoundTable. As we have seen before, PostScript is now the ultimate hacker's language.

Or, you could go into the lab and use a wattmeter and a variable load resistor. Which should give you the same curve, again with its maximum value matching your source.

Let's try using some math instead. There's this ugly rumor going around that electrical circuits will obey math rules. And that you can predict what they will do simply by looking at the underlying math.

In the figure one circuit, we have a voltage divider which attenuates our one volt input by…

$$e_{out} = R/(1 + R)$$

Your output power should be this voltage squared divided by the load resistance. Which simplifies to…

$$P_{out} = R/(1 + R)^2$$

You or a computer can then plot this curve for different values of R to generate the max power curve.

By the way, this stunt of using one volt generators with one ohm source impedances is called *normalization*. If you can ever analyze something using easy numbers instead of hard ones, it will usually pay to do so. Anything that can be scaled can also be normalized. Much more on this in my *Active Filter Cookbook*.

But there is a much better way to find your maximum power transfer point. There is a math process called *max-min theory* that easily lets you find maximum or minimum points for any reasonable curve. Figure three shows you the key secret.

Any reasonable curve will also have a *slope*. A slope is simply the "steepness" or the "rise over run" of any tiny portion of the curve. One crude way to find the slope of any point on a curve is to take a point just before and one just beyond and create a tiny triangle out of it. The rise/run (or *tangent*) of the triangle will equal the slope of your curve.

As figure three shows us, there are only *three* possible cases where you can get a zero slope on a curve. These happen only at a *local maximum*, at a *local minimum* or, more rarely, at an *inflection point*. And that's all there is to max-min theory.

Just find the math expression for the slope of your curve. Set it to zero and solve it. All solutions will be a max, a min, or an inflection point.

How can you tell which is which? Often, it will be completely obvious. If not, you'll go one step further and find the *slope of the slope*. If you are at a local maximum (3A), the rate of change of slope will be *negative*. At a minimum, (3B), the rate of change of slope will be *positive*. And if you are now at an inflection point, the rate of change of slope will be *zero*.

Your "correct" and "exact" way to determine the slope for any curve is known as *finding the derivative* and this whole field is called *differential calculus*. You could find a full set of rules in any university level Calculus 101 text. A good listing also appears in the *Mathematical Tables* from the *Handbook of Chemistry and Physics*.

I've shown how you use max-min theory to prove the maximum power transfer theorem in figure one. Sure enough, the maximum is *exactly* at a load impedance which matches the source. Taking most derivatives is quite simple. For instance, a parabola $y = x^2$ has a slope anywhere of 2x. Good old $u^n du$ and friends.

Advanced math can be neat stuff. And very valuable, too.

SETI Resources

NASA has recently started a new and very aggressive SETI (search for extraterrestial intelligence) program. In the first few hours of operation, more frequencies have been observed in more ways than have in the *entire* history of *all* previous ET watching.

One prominent researcher in SETI is Frank Drake. He is famous for the "Drake Equation" which accurately predicts the number of intelligent civilizations and unintelligent senators that are likely to be lurking in the universe at any given time. Frank has recently authored a new and highly readable book titled *Is Anybody Out There?* and published by *Delacorte*.

So, I thought it might be a good time to do a resource sidebar on SETI. I've included several associations and a listing of the better books.

Besides the three groups Frank mentioned in his book, I've added the *Amateur Radio Astronomers* who also publish a *Radio Observer* newsletter. But note that their main focus is on radio astronomy fundamentals. And that they do distance themselves from ET watching and the UFO crowd.

For several reasons, I strongly feel that the odds for an imminent SETI contact are quite high. As openers, our signal detection, processing, and computing abilities have skyrocketed in the last several years. And should

With an **OPEN CIRCUIT**, 1600 volts is routed to an infinite resistor. The total delivered load power is **ZERO**.

With an **MATCHED LOAD**, 800 volts is delivered to a 10 meg resistor. Total delivered power is a fairly respectable **640 MILLIWATTS**.

With a **BADLY MISMATCHED LOAD**, 1.6 millivolts is delivered to a 10 Ohm incandescent lamp. The total delivered power is a useless **256 NANOWATTS**.

With a **MATCHED LOAD**, nearly **640 MILLIWATTS** can be delivered to the incandescent lamp by using a 1000:1 turns ratio matching transformer.

With an **SHORT CIRCUIT**, 0 volts get sent to an 0 Ohm resistor. The total delivered power will be **ZERO**.

Fig. 3 – GROSSLY MISMATCHING your source and load impedances can severely reduce your total available delivered power. Here are examples that try to use a piezo striker as a power generator.

SETI RESOURCES

Associations:

Amateur Radio Astronomers
247 North Linden Street
Massapequa NY 11758
(516) 798-8459

Planetary Society
65 North Catalina Avenue
Pasadena California 91106
(818) 793-5100

Pacific Astronomical Society
390 Ashton Avenue
San Francisco, Califronia 94112
(415) 337-1100

SETI Institute
2035 Landings Drive
Mountain View California 94043
(415) 961-6633

Publications:

Edward Ashpole, *Search for Extraterrestrial Intelligence*, Blandford, 1989.

Issac Asimov, *Asimov's Biogaphical Encyclopedia*, Doubleday,1972.

John Billingham, *Life in the Universe*, MIT Press 1981.

Howard Blum, *Out There*, Simon & Schuster 1990.

Ben Bova, *First Contact*, New American Library 1990.

Ronald Bracewell, *The Galactic Club*, Stanford Alumni, 1974.

A.G. Cameron, *Interstellar Communications*, W. Benjamin, 1963.

Nathan Cohen, *Gravity Lens*, John Wiley, 1988.

Frank Drake *Intelligent Life in Space*, MacMillian 1962.

Frank Drake, *Is Anyone Out There?* Delacorte Press, 1992.

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Fig. 4 – NEW SHARP OPTO CHIPS offer all sorts of new possibilities for wireless communication, safety isolation, and short haul telemetry. The 500 kHz pulse modulation ignores ambient light and TV/VCR remotes.

continue to do so.

Shortly after World War II, our sun suddenly turned into a radio star.

Captain Video, *Roller Derby*, and *Kukla, Fran, & Ollie* became our first goodwill ambassadors to outer space. These signals are now 45 light years away from us, and have now swept out nearly a third of a million *cubic light years* of space.

Within this humongous volume are several hundred "probable" candidate star systems. Our own signals are easily detectable at this range with our present state of the electronic art. In another 45 years, *eight times* more volume will be swept out with eight times more candidate star systems now watching *Your Hit Parade*.

At a further signal strength drop of less than six decibels!

We are now in transition between calling hundreds of candidate star systems to annoying thousands more.

On the other hand, I personally feel that looking for obviously modulated narrow SETI signals in the expected "water hole" frequency band might not be the swiftest way to go. If Earth is an even remotely typical example, all the *unintentional* radiated signals swamp those *intentional* ones by at least a zillion to one.

And we have recently discovered spread spectrum communications. If you really want to punch any signal through very high noise over great distances, spread spectrum seems a very good way to go. The chances are that you could step up to multiple dimensions of spectrum spreading.

Using, say, frequency, time, and some sort of a trellis modulation type of overlay.

Perhaps a "multi-level marketing scheme" in which the unswift could pick up that something was coming down, the fairly bright could receive useful info, and the superintelligent could grab the full set of plans. This surely would beat sending out prime numbers forever.

The signals may be there but we just might not be smart enough to recognize them just yet. Perhaps the fundamental question to ask is "What spreading and modulation scheme would give us the most bang for the buck?" And then start looking for something similar heading our way.
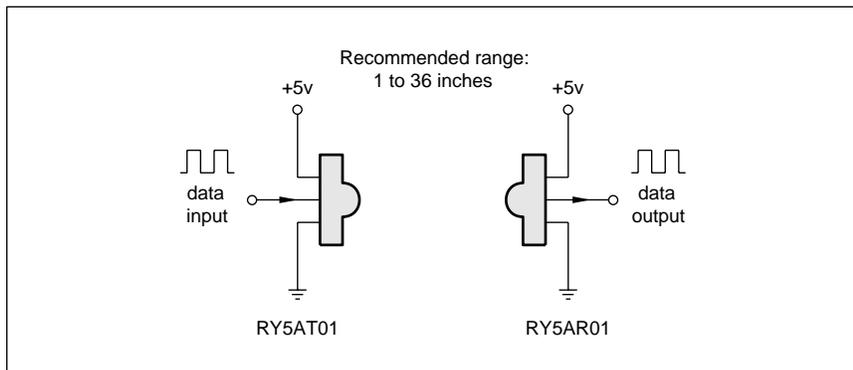
Let's have your thoughts on this.

New opto chips

Infrared data communications has recently become much simpler thanks to a pair of *Sharp* circuits. Figure one shows details.

These devices look like a transistor with a built-in lens. Their RY5AT01 transmitter outputs a burst of 500 kHz modulated infrared square waves if fed a logic one. And outputs nothing with a logic zero. This is a form of modulation that's called *Amplitude Shift Keying*.

The RY5AR01 receiver accepts an infrared signal and converts it back into digital logic levels. An internal digital filter rejects most interfering signals or noise.

The modulation scheme largely ignores ambient light. Signals from most interfering TV or VCR remotes are also strongly rejected. Data rates up to 19,200 baud are supported. The beamwidth is a somewhat narrow ten degrees, and the recommended range is 1 to 36 inches.

Obvious hacker uses include safety isolation, data comm, handicapped aides, virtual reality, robotics, and for wireless mice.

Because of the narrow beamwidth, the two devices must point *directly* at each other at all times. While there is good rejection to ambient light and many random IR signals, there is no selective coding. Which means that you will have to strictly isolate each optical linkup from any potentially interfering neighbors. This turns into an especially sticky problem in full duplex (two-way) data comm.

Sadly, Sharp's $10 intro price for these is in the "What are they on, and where can we get some of it?" range. These will be superb products when they drop to sixty cents each.

Short haul telemetry

There are all sorts of emerging new uses for shorter range wireless data communication. I'd like to apply the generic term *short haul telemetry* for any newer method that tries to send information a few inches or a few feet without any wires.

We've seen one possible need in a previous column and in my ongoing *Hardware Hacker* BOD reprints.

An *Isopod* is a tennis-ball shaped beastie that you glomp onto an ac

power wire. The isopod automatically measures and transmits the current to a nearby receiver. This can greatly simplify home energy management. No rewiring, no electricians, and no code hassles need be involved.

Another new need is for a wireless pulse rate sensor for use on a bicycle computer. And there are thousands more. How about an "optical mouse" that senses where you are *looking*? Or new ways to get data onto or off of a rotating shaft or moving vehicle. Or ground-loop-free alternatives to data communications?

But why don't you tell me instead? For this month's contest, either (A) show me a use for the RY5AT01 and the RY5AR01, or else (B) dream up a brand new application for short haul telemetry.

There will be dozens of the usual *Incredible Secret Money Machine II* book prizes awarded, along with an all-expense paid (FOB Thatcher, AZ) *tinaja quest* going to the best of all.

Be sure to send your written entries to me here at *Synergetics* and not to **Electronics Now** editorial.

New tech lit

From *Signetics*, a new and thick *Desktop Video Data Handbook* chock

full of A/D, D/A and DSP chips. Also included are their genlocking video encoders.

From *NEC* a large packet of data sheets on *Infrared Control ICs*. Yes, these definitely include the fancy new teachable versions.

RF Design is a trade journal which covers radio communications in the VHF and UHF range. Lots of ads for specialized chips and components here. And *Wired* is a brand new mag out of Multimedia Gulch that is quite interesting but hard to describe. The stories so far have included ones on cellular hacking and virtual reality.

Plotter codes appear in the *Plot Data Format Reference Book* from *Gerber*. This includes photoplotter and vinyl sign cutter info.

From *Cerac*, a freebie pocket size periodical chart of the elements.

For the fundaments of most digital integrated circuits, be sure to check into copies of my *TTL Cookbook* and *CMOS Cookbook*. Both are available per my nearby *Synergetics* ad.

Most of those items I've mentioned do appear in our *Names & Numbers* or *SETI Resources* sidebars. Be sure to check here first before calling our helpline.

Let's hear from you.✦

NAMES AND NUMBERS

Cerac Inc
Box 1178
Milwaukee, WI 53201
(414) 289-9800

Delacorte Press
666 Fifth Avenue
New York, NY 10103
(212) 765-6500

GEnie
401 N Washington Street
Rockville, MD 20850
(800) 638-9636

Gerber Scientific
83 Gerber Road
South Windsor, CT 06074
(203) 644-1551

NASA
Langley Research Center
Hampton, VA 23665
(804) 865-3281

NEC
401 Ellis Street
Mountain View, CA 94039
(800) 632-3531

Radio Observer
7605 Deland Avenue
Ft Pierce, FL 34951
(407) 464-2118

RF Design
6300 S Syracuse Way, S650
Englewood, CO 80111
(303) 220-0600

Sharp
5700 NW Pacific Rim Blvd.
Camas, WA 98607
(206) 834-2500

Signetics/Philips
811 E Arques Avenue
Sunnyvale, CA 94088
(800) 227-1817

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

Wired
544 Second Street
San Francisco, CA 94107
(415) 904-0664

Don Lancaster's
Hardware Hacker

A flying car newsletter
Photopolymer resources
Amateur television books
Royalty-free real PostScript!
BASIC Stamp microcontroller

July, 1993

A reminder once again that I do try to gather most of our mentioned items into a pair of sidebars. You will usually find one for all the regular *Names & Numbers*, and a second that targets a special resource category.

We try to triple check all entries. First by my own research. Second by Kathy, our superb proofer and fact checker. And third by EN editorial spot checks.

To date, I have received over *two hundred* helpline calls asking me for the *Integrated Circuit Systems* source from two columns back. Well, it was right where it belonged. Smack dab in the middle of that *Names & Numbers* sidebar. Complete with reader service number.

Before calling my no-charge tech helpline, please read the *entire* story, double check both sidebars, and have a pencil or pen ready.

A new microcontroller

As figure one shows us, the *BASIC Stamp* from *Parallax* is a brand new $39.00 hacker computer the size of a commerative postage stamp. This is basically a PIC16C56 microcontroller, a 256 byte EEPROM, a resonator and a voltage regulator. Eight I/O lines form your real world interface. These are provided for in a breadboard area. *Microchip Technology* is the supplier of the CPU.

This one is cute as a bug.

An approximate schematic appears in figure two. Burned into the custom CPU is a BASIC interpreter. The fully tokenized instructions are prestored into the companion serial EEPROM and then automatically interpreted on each power up.

The *total* program and data storage area is only 256 bytes in the EEPROM plus an additional 16 internal working registers.

No, you can not run multi-tasking UNIX on this machine. But since each tokenized BASIC command requires only a very few bytes, and since some *very* fancy macros are available, you can create surprisingly sophisticated programs on your own.

Program development is normally done on your PC host, using the fancy editor and interpreter provided. On the host, you are working directly in BASIC. And have all of your normal resources available. The interpreter then tokenizes the final program and uploads it to the BASIC Stamp via a three-wire cable that connects to your host's parallel port.

Once uploaded, your BASIC Stamp becomes a dedicated computer which can be used just about anywhere.

Power can come from a clip-on 9 volt battery. Power consumption is an impressive *2* mils when running and a mere 20 microamps when asleep.

Figure three shows the instruction set. Besides all the usual tiny BASIC commands, there are some powerful macros offered. BUTTON debounces input contacts. With a lot of options.

DEBUG returns variables to your host for debugging and analysis. A BRANCH macro offers a direct option picking. Just like the CASE command in fancier languages.

PAUSE gives you selectable time delays. POT is an 8-bit A/D converter that reads a potentiometer input. It can also read a photocell, thermistor, or whatever. PULSIN can measure the duration of any input pulse with a ten microsecond resolution. The similar

Fig. 1 – THE BASIC STAMP is a $39.00 hacker microcontroller using a Microchip Technology CPU.

PULSOUT command delivers a timed output signal.

PWM directly outputs pulse width modulation. Adding a resistor and a capacitor can change this to an 8-bit accurate analog voltage.

Now for the neat stuff. The SERIN macro is a full serial data receiver with selectable baud rates from 300 to 1200. This can become *self-qualifying* in which you can wait for a specified character sequence. SEROUT directly generates serial output data for RS623 use. RS232 with an external driver.

A SOUND output can produce 128 tones and 128 noise effects.

A RANDOM number generator is even included. Use this one for white noise audio sources or to randomize video game effects. Naturally, you can selectively read, toggle, or write any individual I/O line. You can also temporarily or permanently go into sleep mode. You get out of the sleep mode by cycling your power off and then back on. Sixteen subroutines are allowed, nested two deep.

The PIC series of microcontrollers use a non-Von RISK architecture. The 12-bit instruction words are used in conjunction with 8-bit data words.

The chips by themselves (less any custom operating system code) can be bought for as little as $2.70 each.

See the *MicroChip Data Book* and their companion *Embedded Control Handbook* for additional details.

Speeds? The PIC series blows away pretty near all of their competition in execution time and code length.

On the other hand, serial EEPROM access for your tokens does slow you down considerably. But hundreds of internal machine language commands may get executed at full speed for any one token fetch. Clock frequencies as high as 20 Megahertz can be used. So long as low power is not critical.

One possible trick: Use the BASIC Stamp to develop your ap. Then you switch to plain old machine language for full speed and ultra low cost on your production units.

Much more on the fundamentals of working with microcontrollers can be
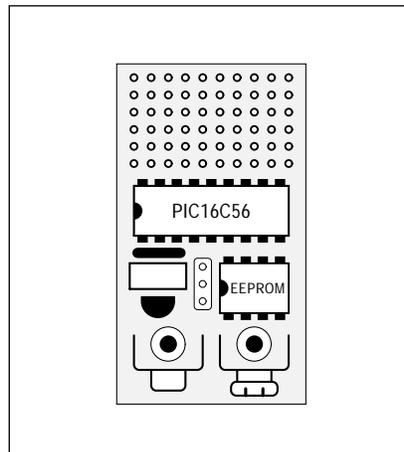
breadboarding area

+Vin

+5v

I/O line #7
I/O line #6
I/O line #5
I/O line #4
I/O line #3
I/O line #2
I/O line #1
I/O line #0

4 Mhz
piezo
resonator

+5v

18 17 16 15 14 13 12 11 10
RA1 RA0 OSC CLK +5V RB7 RB6 RB5 RB4

PIC16C56

RA2 RA3 RTC CLR GND RB0 RB1 RB2 RB3
1 2 3 4 5 6 7 8 9

nc

8 7 6 5
VCC PRE PE GND

93LC56

RA2 RA1 CLK CS
1 2 3 4

sip
network

programming
connector

5 volt
reg

in
gnd
out

(+)

.005
µF

10
µF

+Vin 9-volt
battery
connector

+5 volt source
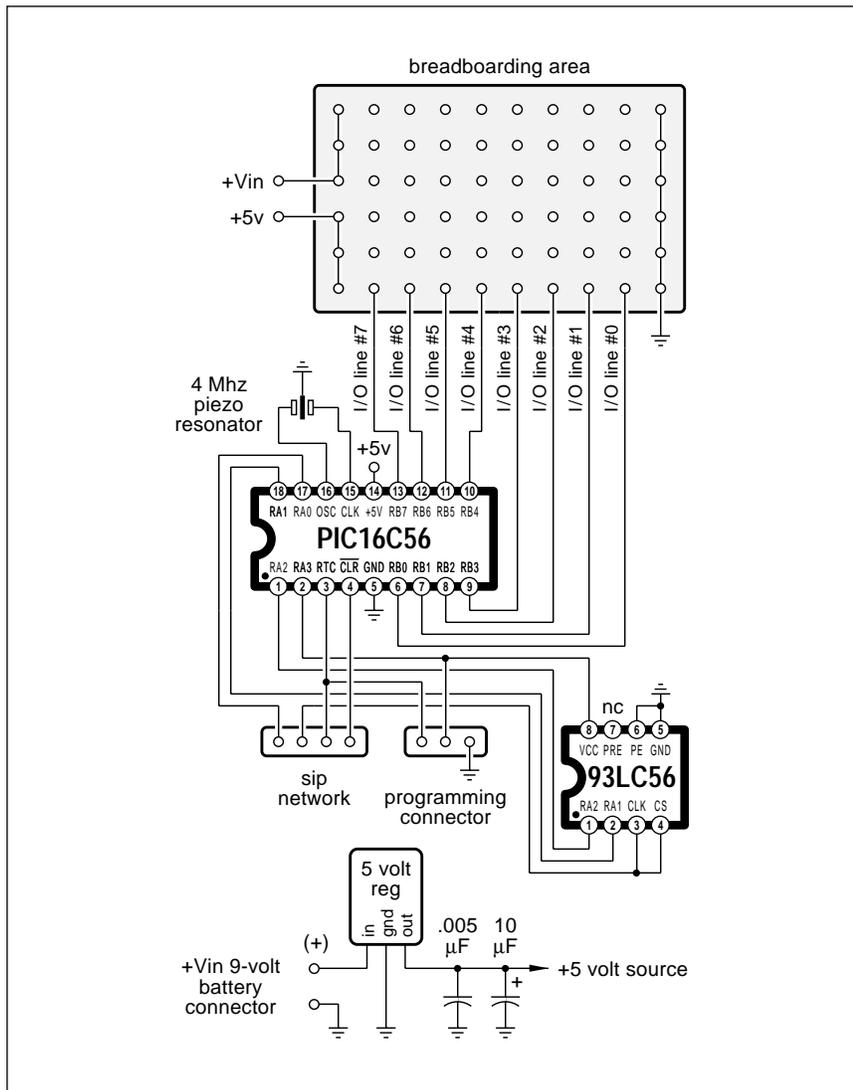
Fig. 2 – SCHEMATIC DIAGRAM of the BASIC Stamp.

found in my older *Micro Cookbooks*, volumes I and II.

Homebrew PostScript hacking

One potential use for the BASIC Stamp is shown in figure four. I've been doing a lot of work with the stupendously great PostScript general purpose computer language. In fact, this is the *only* language I use for *all* of my electronic design, pc layouts, stock market analysis, schematics, Book-on-demand publishing, and just about everything else.

All the *camera ready* figures you have seen here in *Hardware Hacker* for years have been done by using nothing but my word processor and PostScript. Device independently.

The only little problem has been that PostScript I/O tends to end up a tad on the skimpy side. Usually you only have three choices: Dirtying up otherwise clean sheets of paper or plastic; writing files to the hard disk; or returning your data back to a host for recording or other reuse.

The BASIC Stamp can instantly let you extend the genuine Adobe Level II PostScript to any personal project or machine of your choosing!

Assume you've got a homebrew machine that has an x-axis and y-axis stepper, an up/down mechanism, and a "both steppers home" sensor. This can be a vinyl signcutter, engraving, or embroidery setup. Or an automated printed circuit drill, a wooden sign

router, or a Santa Claus machine.

You could use two of your BASIC Stamp lines for RS423 serial comm with your PostScript printer. Use two lines for both x-axis stepper phases. And two lines for those y-axis stepper phases. One line for pen or drill or whatever up/down. And a final line that zeros only when both steppers are in their home position.

The hidden beauty here is that all of those fancier PostScript fonts and the level 2 tools immediately become available for use on your own custom homebrew rig. At unbelievably low cost. With *zero* royalties!

Do let me know if you want more details. Meanwhile, I've posted lots more on PostScript to *GEnie* PSRT.

In particular, be sure to check out STARTUP.PS for an intro PostScript tutorial, and POSTVECT.PS for lots of details on vector output. I've also got a free PostScript secrets brochure to get you started.

Ferinstance, say you lash up your own vinyl sign cutter. You use your PostScript printer to create, debug, and proof all the artwork. Then you can capture the graphic paths by using PostScript's rather powerful *flattenpath* and *pathforall* operators. Next, you use POSTVECT-like code to vectorize the captured paths.

Finally, a series of *print* commands sends your cutting sequences out the serial port where the BASIC Stamp can act on them. Should any longer sequences be needed, serial feedback can be used with a *readchar* sequence to wait for task completion.

Thoughts on a PC drill

The really big hacker breakthrough that everyone is waiting for is a $199 automated printed circuit drill. The new BASIC Stamp used along with a PostScript printer seems to give us a brand new handle on this project.

I recently noticed that dentist's air turbines cost only $30. Junkers might end up free from a reasonably curious dentist. The handle on most drills is usually empty. These turbines can be cut down to the size and roughly the mass of a plotter pen. It sure would be interesting to see if they provide enough power for board drilling.

Let's restrict our goals initially to a 4" x 6" board. An X-Y system might introduce all sorts of bad mechanical

problems. Instead, the board could be moved along a single axis. The drill could be moved along a second axis. And it might be simplest to *lift* your board, rather than drop the drill. Or maybe use a raising cam and gravity feed on the turbine.

My current thinking for a stepper would be the linear *Hurst* SLS. While kinda pricey, this does offer twenty pounds of force in two mil steps. And *Texas Instruments* offers some dandy new peripheral driver chips.

Let me hear your thoughts on this great new project.

Fun with photopolymers

I have long been fascinated by the *photopolymers*. These are just plastic compounds of one breed or another which are only partially cross-linked during manufacture. A later exposure to light and a development process will selectively harden portions of the material. Which can result in a state change from liquid to solid or a shift in dissolvability.

The results could be used for etch resists, a 3-D model, a Braille sign, a rubber stamp, a printing plate, an integrated circuit mask, a silk screen master, or a vinyl stick-on letter. Or for zillions of new aps.

Because of fundamental chemistry, most photopolymers demand strong ultraviolet light for exposure. Three minutes using a contact printer out in direct sunlight often will work well. Photopolymers are typically *negative acting*, hardening in the presence of light.

This month, I thought our resource sidebar might give you a rundown of the more hackable photopolymers.

The classic one you might be most familiar with is spray-on etch resist, often in the form of KPR by *Eastman Kodak*. And stocked by *Radio Shack*. More modern substitutes are the *dry film photoresists* such as those now offered by *Dynachem*. These are both uniform and pinhole free. They also develop with sodium triphosphate, a low cost garage floor cleaner.

Kepro is a fine stocking supplier of printed circuit supplies. A good trade journal here is *Circuits Assembly*.

Photopolymer solder mask resists are also readily available.

Photopolymers offer lots of options for silk screen printing. The leading film supplier is *Ulano*, while *Advance Process Supply*, *Southern Sign*, and *Dick Blick* offer smaller quantities.

3-M, the *Scotch Tape* folks, have a number of interesting photopolymer products. One is known as *Color Key*. Actually, this is more a diazo-like process, but it uses the same drill of contact print exposing and wiping on glop to alter selected areas. What you end up with is a clear polyester sheet that has translucent or opaque color areas selectively applied to it. Dozens of color options. Lots of graphic arts uses here.

Their *Dynamark* imaging products seem great for labels and prototype dialplates. Typically, you will have a white self-stick vinyl having a color overlay. You then selectively remove the color by exposing. Then you use a wiper pad to develop. Any "reverse" effects get done by using positive art.

Aluminum backed versions are also offered. Price is in the $8 per square foot range.

The photopolymers have long been essential for *flexographic* printing as used on cardboard containers. One leading supplier for the materials in larger quantities is *Merigraph*, while *R. A. Stewart* is a wholesale source in more modest amounts.

The same material can make great "rubber" stamps. Any "real" rubber stamp will be pink or black, while a photopolymer stamp will be clear to translucent. The photopolymer ones often last longer and provide sharper images. Of the many rubber stamp photopolymer suppliers, *Grantham Polly-Stamp* and the *M&R Marking Systems* are my favorites.

We've seen in previous issues how Santa Claus machines are starting to revolutionize prototyping. A leading

BRANCH	Option picker similar to a CASE command.*
BUTTON	Read and debounce mechanical input.*
DEBUG	Send register contents to host.*
EEPROM	Store data in memory.
END	Go into sleep mode until power cycles.
FOR...NEXT	A looping construct.
GOSUB	Execute subroutine.
GOTO	Jump to another location in program.
HIGH	Make the chosen I/O pin high.
IF...THEN	Conditionally execute instructions
INPUT	Make selected pin an input.
LET	Optional definition. Includes add, subtract, multiply hi/lo, idivide, modulo, min, max, AND, NAND, OR, NOR, XOR, and NXOR.*
LOOKDOWN	Search table for match.*
LOOKUP	Read values from table.*
LOW	Make the chosen I/O pin low.
NAP	Enter sleep mode for a selected time.*
OUTPUT	Make the chosen I/O pin an output.
PAUSE	Short selected time delay.
POT	Read a potentiometer (8-bit A/D convert).*
PULSIN	Measure input pulse width.*
PULSOUT	Output pulse of selected width.*
PWM	Output pulse width modulation (D/A convert).*
RANDOM	Generate pseudorandom number.*
READ	Read variable from memory.
RETURN	Return from subroutine.
REVERSE	Change direction of selected I/O pin.
SERIN	Read serial input and interpret format.*
SEROUT	Format and output serial data.*
SLEEP	Long selected time delay.
SOUND	Output musical notes or white noises.*
TOGGLE	Change state of selected I/O pin.
WRITE	Store data to memory.

Fig. 3 – INSTRUCTION SET FOR THE BASIC STAMP. The macros marked (*) above make the stamp surprisingly powerful.

PHOTOPOLYMER RESOURCES

Advance Process Supply
400 N Noble Street
Chicago, IL 60622
(312) 829-1400

Dick Blick
Box 1267
Galesburg, IL 61401
(800) 447-8192

Cooley Sign Systems
50 Esten Avenue
Pawtucket, RI 02860
(800) 992-0072

Dynachem/Thiokol
2631 Michelle Drive
Tustin, CA 92680
(714) 730-4200

Dynamark
3M Center Bldg 220-7W-03
Saint Paul, MN 55144
(800) 241-4819

Eastman Kodak
343 State
Rochester, NY 14650
(716) 724-4000

Grantham Polly-Stamp
418 Central Avenue NE
East Grand Forks, MI 56721
(218) 773-0331

IMEC
Rt 4, Box 79
Monell, MO 65708
(417) 235-3053

Jet USA
1116 MacDate Boulevard
Collingdale, PA 19023
(800) 528-1153

Kepro Circuit Systems
630 Axminister Dr
Fenton, MO 63026
(800) 325-3878

Kimoto
2915 182nd Street
Redondo Beach, CA 90278
(213) 370-7411

M&R Marking Systems
100 Springfield Avenue
Piscataway, NJ 08855
(908) 562-9500

Merigraph
Box 3064
Naperville, IL 60566
(800) 323-1832

Southern Sign Supply
127 Roesler Road
Glen Burnie, MD 21060
(410) 768-8600

RA Stewart
641 S Palm, Unit H
La Habra, CA 90631
(310) 690-4445

3-D Systems
26081 Avenue Hall
Valencia, CA 91355
(805) 295-5600

3M/Color Key
3M Center Bldg 223-2N-01
Saint Paul, MN 55144
(800) 328-1303

Ulano
255 Butler Street
Brooklyn, NY 11217
(718) 622-5200

Fig. 4 – THE BASIC STAMP can be used as a royalty-free interface to let you apply real Adobe PostScript level 2 to any old homebrew project!

firm here that uses ultraviolet curing photopolymers is *3-D Systems*. More on Santa Claus stuff in future issues and the *Hardware Hacker* reprints.

The photopolymer that I am really waiting for is a vinyl one which has only been partially cross linked. You do your PostScript artwork master on your laser printer and then you'll contact print. Expose and then wipe on some glop. A repositionable and pre-weeded cut vinyl letter or a logo results. Without needing a costly sign cutter. I do keep hearing persistent rumors of these. But no results.

Meanwhile, there are now two new products that come close.

One of these is that *Etch-n-Peel* system by *Kimoto*. This is basically a self-stripping "rubylith". While great for its intended graphics art stripping purposes, you are stuck with red, and the results are not repositionable.

The other one is known as *Cooley Brite Eradicable Sign Material*. This is an opaque white and fully outdoor rated reinforced vinyl. Color glop has been preapplied to its surface. In your choice of seventeen flavors.

A magic developer will dissolve *only the color*. To do this, put a vinyl cover (or any suitable mask) onto the material. Then simply scrub the color away in selected locations.

In the daylight, you have a color over white. At night and backlit you get white light or translucent colors per your selection. Neat stuff. Sanely priced. And eminently hackable.

Finally, there is an interesting new variation on photopolymer printing plates that should open up all sorts of new hacker ideas. The *Jet USA* folks are using photopolymers for Braille and other low cost raised letter ADA signage. What you really have here is a metal plate with some raised plastic selectively applied exactly where you want. Unique business cards are one possibility.

There is a slight chamfer to their resin, improving the appearance. Cost is in the twenty cents per square inch range. Jet's processing equipment is ridiculously expensive, but it should be easy enough to fake.

Their photopolymer offers a very high durometer. Free samples.

Needless to say, *any* hacker work involving photopolymers can be very much improved by using PostScript.
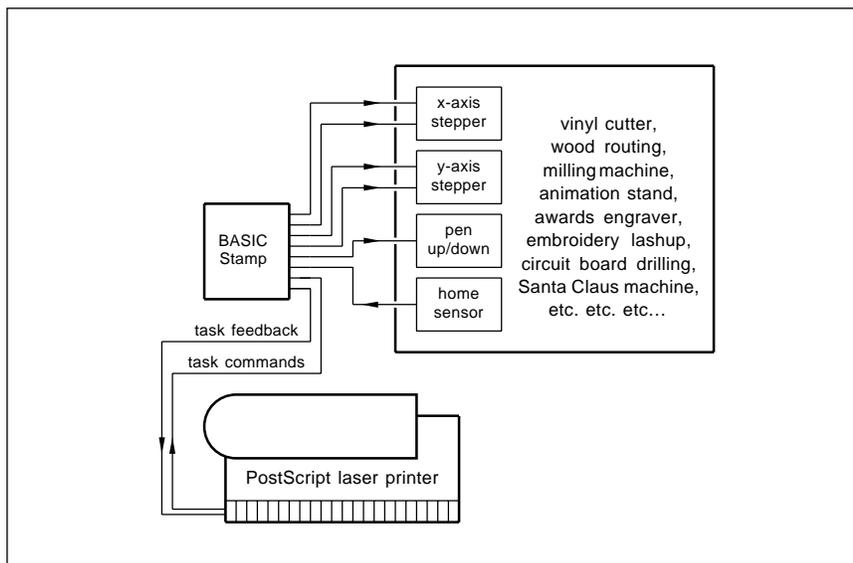
Full details on *GEnie* PSRT. One little known capability of PostScript is its *microsizing* ability. This lets you get the final size of your printed circuit layout exactly right, even on a printer with sloppy tolerances and paper that swells or shrinks.

In flexographic printing and other places where images stretch as they are bent around a drum, anamorphic scaling using PostScript gives you a fast, simple, and accuracte fix.

Two contests

Let's have two contests this month. Either (A) dream up a new ap for the BASIC Stamp, or else (B) see if you can come up with some non-obvious hacker use for photopolymers.

As usual, there will be a dozen or so of my recently updated *Incredible Secret Money Machine* book prizes, along with an all-expense-paid (FOB *Thatcher,* AZ) *tinaja quest* for two going to the very best of all.

Be sure to send your *written* entries directly to me here at my *Synergetics*, and not to **Electronics Now** editorial.

Let's hear from you.

New tech lit

We have a super selection of new goodies this month. For great books and mags on ATV, try out the *Amateur Television Quarterly* folks.

Gyro Gearloose is alive and well! *Roadable Aircraft* is a unique labor of love Ron Borovec newsletter for all of you flying car enthusiasts. Similar pubs include *Experimental Aircraft* from the *EAA Aviation Center* and the *Experimental Rotorcraft* from *Rotary Flight International*

All the fundamentals of telephone operation are well covered in a new self-published *Tech Notes from a Telephone Engineer* by Dan Levels.

Science Under Siege is a new book by Michael Fumento. It explores the nature of evidence and statistics in a scientific controversy, and does cover everything from the Alar worries to ELF radiation. In a typical chapter, strong evidence is given that alcohol is one outright scam rather than any useful motor fuel. Grain alcohol uses much more energy than it delivers and increases air pollution. This one is a must read.

The *Colorado School of Mines* just completed their fourth *Subsurface*

NAMES AND NUMBERS

Amateur Television Quarterly
1545 Lee Street
Des Plaines, IL 60018
(708) 298-2269

Colorado School of Mines
SPACE
Golden, CO 80401
(303) 273-3321

EAA Aviation Center
3000 Poberezny Drive
Oshkosh, WI 54903
(414) 426-4800

GEnie
401 N Washington Street
Rockville, MD 20850
(800) 638-9636

Hurst Manufacturing
Box 326
Princeton, IN 47670
(812) 385-2564

Integrated Circuits Systems
PO Box 968
Valley Forge, PA 19482
(215) 666-1900

Dan Levels
PO Box 1125
Tellevast, FL 34270
(813) 356-2788

McMaster-Carr
Box 54960
Los Angeles, CA 90054
(310) 692-5911

Microchip Technology
2355 W Chandler Blvd
Chandler, AZ 85224
(602) 963-7373

MSC
6700 Discovery Blvd
Mableton, GA 30059
(800) 645-7270

Parallax
6359 Auburn Blvd Ste C
Citrus Heights, CA 95621
(916) 721-8217

Resonance Research
E11870 Shadylane Road
Baraboo, WI 53913
(608) 356-3647

Roadable Aircraft
338 8th Avenue South
Edmonds, WA 98020
(206) 778-0423

Rotary Flight International
5555 Zuni SE #281
Albuquerque, NM 87108
(505) 298-9362

Small Parts
13980 NW 58th Court
Miami Lakes, FL 33014
(305) 557-8222

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

Texas Instruments
PO Box 809066
Dallas, TX 75380
(800) 336-5236

Don Thompson
23072 Lake Center Dr #100
El Toro, CA 92630
(714) 855-3838

Exploration Technology symposium. Mostly on underground radar used for mining, caving, and archaeological uses. Proceedings are available.

A video on *Designing and Building High Performance Tesla Coils* is now available from *Resonance Research.*

New videos, parts kits, and training seminars on laser printer repairs are available through *Don Thompson.*

Small Parts now ships a new and free *Catalog #14.* These folks run the greatest robotic resource in the world. They have everything your hardware store never heard of. And then some.

MSC is a *McMaster-Carr* alternate that carries extensive local stocks of machine shop supplies and hardware. They are also a no-hassle source of the EDM wires and dielectric oils. A 2000 page catalog is offered.

Turning to my own products, my

new *Book-on-demand Resource Kit* contains lots of self-publishing info; and my new *Resource Bin I* gives you insider access to scads of my secret supply sources. Or if you really want to get into PostScript is a big way, try my *Whole Works* package. See my nearby *Synergetics* ad for more info.

Over on *GEnie* PSRT, I have just added NUTS17.PS, a review of ham radio magazines. Or NONLINGR.PS, nonlinear graphics tutorial (use when mapping stuff onto oddball surfaces). Also a reminder that I have arranged for a newer and faster *GEnie* signup. Have your modem dial (800) 638-8369 Then type HHH to set your baud rate. When promped, enter your temporary access code of XTX99005,SCRIPT.

A reminder here that most of the sources mentioned also appear in the *Names & Numbers* appendix. ❖

Don Lancaster's
Hardware Hacker

August, 1993

The GPS logjam seems to be finally breaking up. We have already seen where *Trimble Navigation* offers a Global Positioning Satellite receiver for $390 in single quantities.

Better yet, *Sony* has dumped their *PYXIS* Backpacker's GPS receiver to the yuppy surplus resellers. *Damark* stocks these at $599. But our helpline lore says they are grossly overpriced, even at one-third the original list.

Best of all, *Plessey* has announced a GP1010 receiver front end IC at $21. Along with their companion GP1020 six-channel correlator. Plessey offers pretested GPS receiver boards. Free *if* you can show them any credible plan for engineering a GPS product.

We've seen in previous issues how *GPS World* is a great trade journal for keeping up on the latest and the best developments in personal nav.

We have a mixed bag of goodies for this month…

Nonlinear Graphics

I have long been fascinated by the mapping of images onto distorted surfaces. For "star wars" lettering or drawing on a sphere. Or perspective storefronts. Or words on a blowing flag. Or logos on a rootbeer cup.

I've found PostScript to be ideal for this sort of thing. Let's do a quick summary and then find out where to go for the full set of plans.

There are two key tools needed for fancier graphic mappings. These are the *linear graphics transform* and the exotic *nonlinear graphics transform*. Several examples of what you can do with these appear in figure one.

We have already found out about transforms in previous columns and in those *Hardware Hacker* reprints. A transform is just a way of taking one group of numbers and playing tricks with them to create a new group of numbers. The new group will end up somehow "better." Or more what you have in mind.

In the case of a two-dimensional transform, all you do is take a pair of *x* and *y* values and change them into a

new pair of *x'* and *y'* values that are "elsewhere." The relationship of the "elsewheres" determines the mapping you end up with.

Fancy matrix math techniques are usually used for graphics transforms. Plain old ninth grade algebra can get used just as well. The linear graphics transform is simply…

$$x' = Ax + By + C$$
$$y' = Dx + Ey + F$$

You could view A as the *horizontal scale*. B is the amount of *lean*. C is the *horizontal offset*. D is the amount of *climb*. E is the *vertical scale*. and F is the *vertical offset*.

To move a figure around on your page, you change C and F. This is called *translation*. To make a figure larger or smaller, you change the size of A and E. This is known as *scaling*. Usually, you'll scale A and E by the

same amount. Otherwise you'll get an *anamorphic* scaling that gives you a compression or an extension.

Make A negative, and you'll get a special case of scaling that prints or images ƨbɿɒwʞɔɒd. Make E negative and you go ∩bƨiqɘ qoʍn. Or do both for, of all things, ɥʇoq.

Rotating a figure gets tricky. You use some trig sines and cosines on A, B, D, and E. You might use fancier combinations to do fancier mappings. For instance, that *isometric* mapping shown in figure one can be done with a linear transformation.

The *sequence* of the transforms is critical. Scaling and then translating is vastly different than translating and then scaling. Sure, if you do know exactly what you are doing, you can use one single transform to translate, rotate, and scale all at once.

You can do a surprising amount of
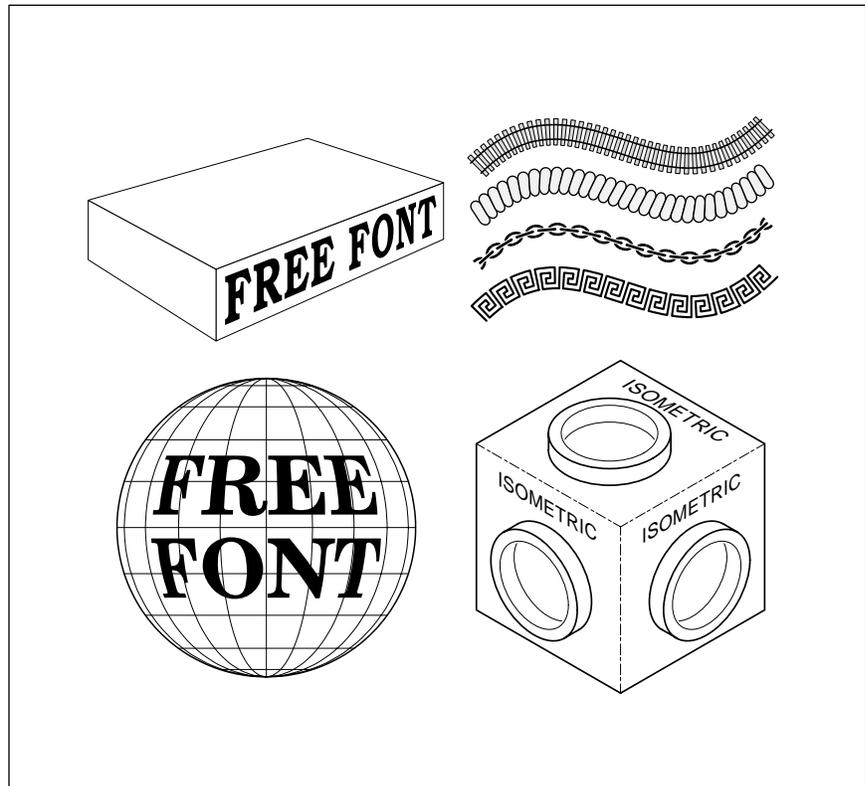
Fig. 1 – TYPICAL FANCY GRAPHIC MAPPINGS. Only the "isometric" figure at the lower right can be done with a stock linear graphics transform. The others require use of nonlinear transform techniques.
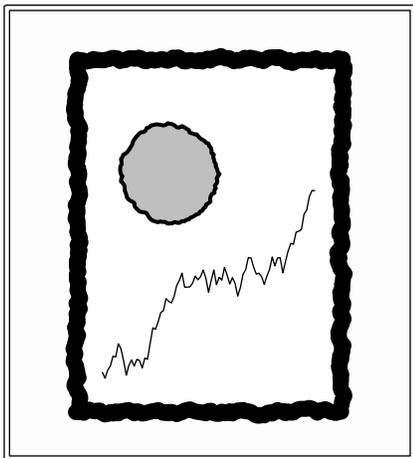
Fig. 2 – THE NONLINEAR "scribble" transform can make computer art less exact and precise.

stuff with a plain old linear mapping. A square could get changed into any other square of any chosen size and orientation and position. Or into any rectangle, line, or point. You can also map into a parallelogram. Or copy any number of times.

But note you can *not* use a linear transform to convert your square into the *trapezoid* needed for perspective lettering. Or to draw on a sphere. Or to scribble. Nonlinear techniques are required for any of these tricks. Since that linear transform is well known

and fast to implement, you usually do a nonlinear transform by *modifying* a linear one.

In a linear transform, the values A through F are *constants* that stay the *same* over the entire mapping. To do a nonlinear transform, you can define A through F as *variables* which may need recalculated for each and every point of the mapping.

Recalculating and retransforming every point can take a very long time. You may have to do this if you are rectifying an aerial photograph.

Instead, you normally want to try and use some *sparse data set* which makes use of graphic *primitives*. This lets you nonlinearly transform *only the ends* of a line segment. Or only the control points of a curve. A linear transform is then used for everything between. Which ends up ridiculously faster and more compact.

Four examples of these graphical primitives are custom *moveto*, *lineto*, *curveto*, and *closepath* procs. Used respectively for positioning, straight lines, curved line segments, and path completion operators.

Nonlinear mapping with primitives should appear "perfect" so long as each straight line ends up as a straight line on the final image. But if you try to map onto a sphere or do anything else where any straight lines become

curves, you'll get into severe *corner cutting* problems. Ferinstance, you might end up running *through* your sphere instead of along its surface.

The workaround here is to change any longer straight lines into shorter segments of "unbent" curves. This can give you reasonable results while still letting you use sparse data.

Doing the Transforms

Each nonlinear transform will end up different, depending on whatever final effect you are after. In general, what you do is intercept your *x* and *y* data values used for positioning and straight lines, or your eight *control points* for any curves. Then for that particular *x* and *y* value, you will then recalculate any of the "constants" A through F which might be sensitive to your current position. Finally, you do the usual linear data transform.

The isometric figure can be done using an ordinary linear transform, since squares are being mapped into parallelograms. Rather surprisingly, the perspective mapping can *almost* be done with a linear transform. Only a single calculation of $(1 - y/y_0)$ need be done nonlinearly ahead of time.

This is for an architect's *2-point* perspective. In which all the vertical lines remain that way, regardless of orientation.

The spherical transform is based on longitude and latitude. Some simple multiplication by sines and cosines do the transformation for you.

The glyphpath transform is very subtle and stunningly powerful. It lets you automatically squash and stretch individual elements as they go along the curve.

You first start with an underlying path that should get broken up into a sequential group of straight line and simple curved path elements. The new transform then places your *x* variable *along* your path and your *y* variable *normal* to your instantaneous path position. Thus *y* always goes to your immediate right or left as you walk along the curve.

The glyphpath transform is best used on "fairly narrow" glyphs. If you get too far from a path which is too tightly turning, you can "inside out" the glyph. With horrible results.

Take apart your next soda cup and look at the lettering. Note how the art

Winegard CA-6065

+10 db amplifier — Radio Shack 15-1117

two-set splitter — Radio Shack 15-1141

To receiver #1

To receiver #2
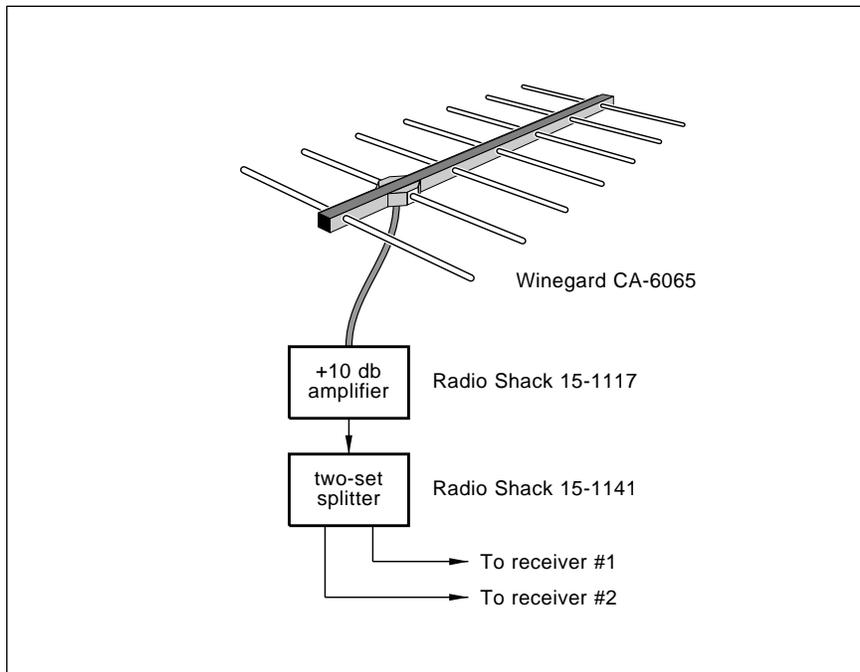
Fig. 3 – FM DX SETUP gives a 145 mile range with a 24 foot antenna height.

has to get fatter as you move to the top of the cup.

The "rootbeer" transform is really drawing onto a truncated portion of a cone. *y* values go radially, while *s* values go tangentially.

Similar techniques can be used for "star wars" lettering, for twisted film effects, stretched banners, or art on a waving flag. Flag waving could be based upon a mapping between two Bezier cubic splines.

Another nonlinear mapping trick is shown you in figure two. Very often, computer art ends up looking like it was done on a computer. Too exact and precise. Nonlinear techniques can get used to let you scribble. Making the results as ratty as you want. Here some random numbers are introduced into the nonlinear mapping.

For More Info

I've posted a complete tutorial and lots of plans for nonlinear transforms up to my *GEnie* PSRT as my file #719 NONLINGR.PS. Rumor has it this one might also show up in the December 1993 issue of *PC Techniques*. Or, I'll be happy to throw in a free copy with any *Synergetics* order.

There's also another dozen files up on PSRT that give you specific hands-on details on specific nonlinear transforms. Included are starwars, perspective, sphere, rootbeer, banner, tuna can, glyphpath, flag, twisted film, and several others.

FM DX Update

We did look into the reception of distant FM stations a number of times in the past. I thought I'd give you a rundown of just what I'm now using, along with several newer schemes for further improvement.

Figure three shows you my present setup. I've now got this humongous *Winegard* #CA-6065 antenna up on the roof. I used a fixed two-mast mount pointing due west. While this slightly cuts the Phoenix response and badly hurts Tucson, it is cheap and rugged. And we do get some high winds here. The antenna height is around 24 feet above ground.

The antenna signal goes to a *Radio Shack* #15-1117 coax inline amplifier. This can make the antenna load more uniform and gives you 10 decibels of gain to comp for the line losses and

signal distribution. On the other hand, the amp probably adds cross-mod and distortion. Results probably would end up about the same without it.

The amplified signal is then routed

to a coax two-set splitter. One output drives a high quality receiver in the living room. The other runs through what used to be the cable system to source an el-cheapo FM receiver in

(A) Use of antenna pattern to "throw a null" at the interference. The wanted station is purposely misaligned from optimum.

(B) Phase cancellation uses two antennas and adjusts the amplitude and the phase of the interfering signal to cancel itself out.

(C) Coax "long line" trap provides a high impedance at the wanted frequency and a low one at the unwanted frequency.
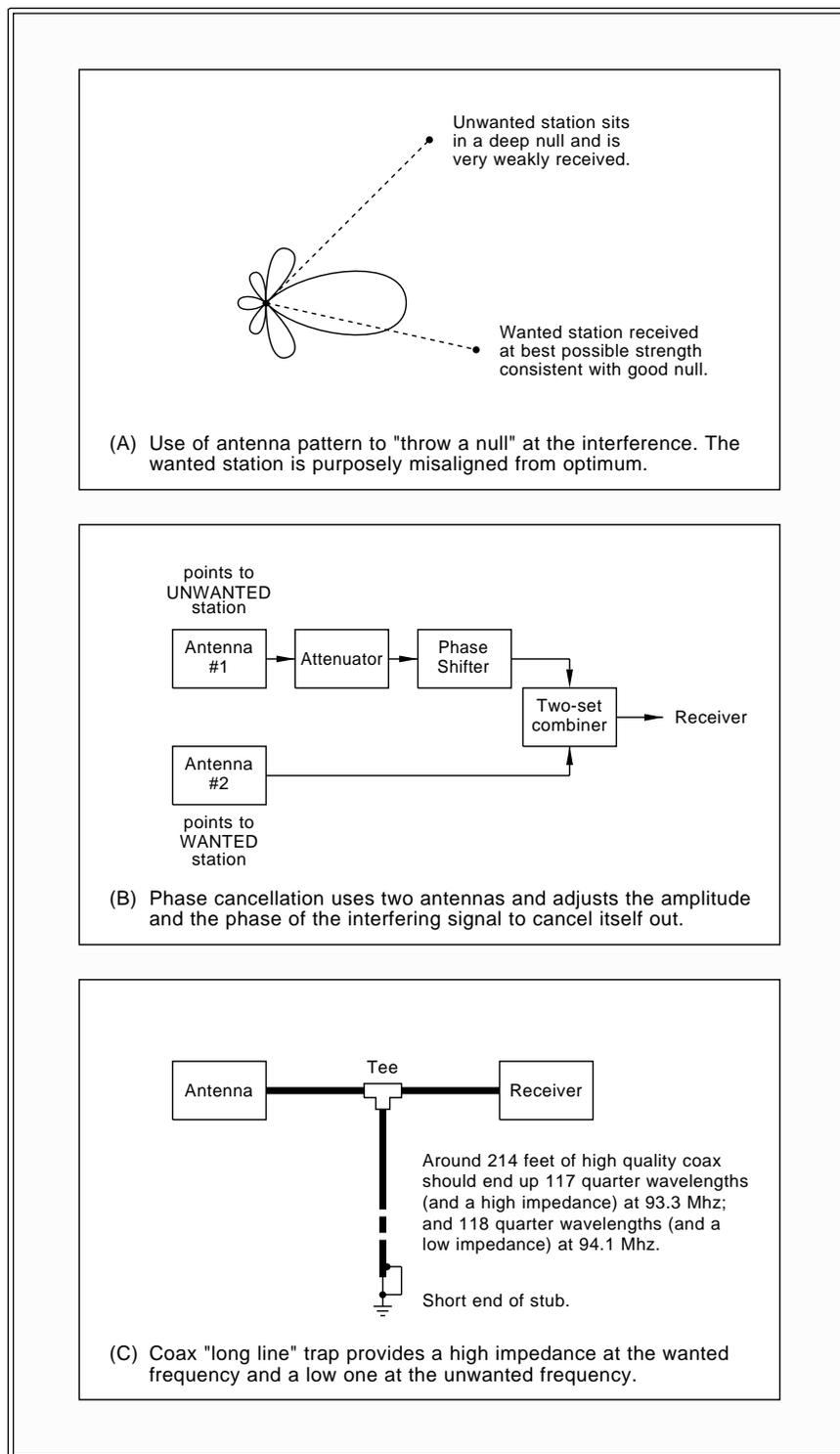
Fig. 4 – SINGLE STATION FM TRAPS are hard to design because of the extreme Q values needed. Here are three creative alternatives.

67.3

my computer room.

The key test here is good old 93.3 KDKB in Mesa, 145 miles away. This comes banging into the good receiver with full stereo and total quieting. On the cheap receiver, it is very hard to tune, slightly noisy, and mono only. The problem is a 50,000 watt random noise source at 94.1 that is only a mile and a half away.

The shielding on a cheap receiver is purposely left off so they get local stations without an antenna.

KJZZ, that Phoenix NPR station does come banging in at 91.5 on both sets so strong that you can arc weld with it. At 158 miles range.

How can you improve on a scene where a strong local station overloads a weak and desired one?

First and foremost, the quality of better grade FM receiver front ends has improved greatly. Key advances are FET transistors having low cross mod and excellent overload specs. And four-quadrant linear multipliers are replacing those flakey old mixers. Getting a newer receiver might help a lot. A mid- to high-end car radio can be a good choice here, because of its better shielding.

Naturally, real coax should always be used instead of twin lead.

Note that any old random hacker junk inserted between your correctly matched antenna and any properly designed receiver is much more likely to hurt you than help.

But there are some things you can try that may help. Some of these are shown you in figure four.

I was very surprised that you can't cheaply pick up a simple one station FM trap. These aren't even available in *Anixter* or other cable-tv suppliers. After making several calculations and

talking to some crystal filter folks, I found out exactly why.

The problem is that exotic high Q components are needed that also have extreme temperature stability. As a general rule, bandstop filters get ugly below 3 percent bandwidth and just about impossible at the 0.5 percent or better often needed for this ap.

The ordinary caps and coils simply won't hack it. Instead, you have to go to exotic crystals, helical resonators, or transmission line components. On passive filters, you have insertion and mismatch losses that could kill any desired but weaker signal. Add gain, and you may pick up cross mod and overload problems that get you right back to square one.

One obvious solution is to perform *spatial* filtering, instead of *frequency* filtering. Any fancy antenna will have one or more deep *nulls* which, when pointed directly at any station, could attenuate it by 30 decibels or more.

Instead of pointing your antenna directly at your desired station, you'll carefully *misalign* it to *throw a null at the interference*. For instance, your desired station might now come in a tad weaker. But the unwanted one can become strongly attenuated.

A second scheme sometimes gets used in radar systems. This one gets called *phase cancellation*. What you do is point your main antenna at the desired station. A smaller antenna is pointed *at the interference*. You then combine your two signals *backwards* through a two set coupler. After very carefully adjusting the amplitude and the phase of the second input signal to give you equal amplitude and 180 degree phase.

Phase is adjusted by changing the lengths of the cables involved. VHF "trombone" lines should be findable as surplus. Amplitude changes can be done using variable resistors or other attenuators.

The theory is to get your residual interfering signal small enough that it doesn't cause cross mod when it hits the receiver.

A *long line canceller* is a possible third interference reduction hack. A shorted transmission line looks like an open at *odd* quarter wavelengths. And appears as a short at *even* quarter wavelengths. In theory, the shorts and opens repeat for longer cable lengths.

Let *n* be any old number. Now, *2n* has to be some *even* number. Every time. And *2n + 1* has to be an *odd* number. By definition.

Let's do a quick calculation to find the *minimum* length of cable needed to get an odd number (and an open) at 93.3 and an even number (and a short) at 94.1 Mhz…

$$93.3 \ (2n + 1) = 94.1 \ (2n)$$

Which solves as 2n = 118.

Your wavelength at 94.1 is 3.19 meters. A quarter wavelength will be 0.80 meters. And 118 of these will be 94 meters total. Assume a 0.7 velocity factor, and this equals roughly 214 feet of coax.

So, take 214 feet of coax, and then solidly short the end and wrap it up inside a well shielded and grounded paint can. Add a T connector to your main antenna line. After carefully adjusting for an exact length, what theoretically should happen is a dead short at 94.1 and an open at 93.3. For reception at other frequencies, you disconnect the coax. Or change its length suitably.

If the wanted station is *higher* than the unwanted one, you should use 2n and 2n-1 instead.

Sadly, the length of the cable will severely attenuate the depth of those shorts and opens. And you probably won't get nearly the Q you need, even when using premium coax.

It might be worth trying, though. Or perhaps something similiar done with stripline on a PC board could get decent Q with acceptable size.

In general, these transmission line components can be cheap and useful substitutes for high Q parts. But the math gets tricky and special test gear may be needed.

Smith Chart techniques can be handy here. Again, check *GEnie* PSRT for do-it-yourself Smith Charts.

Tellyawhat. Let's work up a new group hacker project and a contest out of this. For the usual *Incredible Secret Money Machine II* book prizes plus a possible all-expense paid (FOB Thatcher, AZ) *tinaja quest* for two, either (A) send me the measured FM band reactance plot of a long piece of shorted premium coax, or else (B) show me a single station FM trap that works. Cheap and hacker-friendly, of course. And easily retuned.

NAMES AND NUMBERS

Alpha Supply
PO Box 2133
Bremerton, WA 98310
(800) ALPHA11

Anixter
8101 E Prentice #210
Englewood, CO 80111
(303) 740-8949

Biltrite
PO Box 9045
Waltham, MA 02254
(800) 877-8775

Damark
Box 29900
Minneapolis, MN 55429
(800) 729-9000

Eletech
1262 E Katella Avenue
Anaheim, CA 92805
(714) 385-1707

GEnie
401 N Washington Street
Rockville, MD 20850
(800) 638-9636

Home Automation Laboratories
5500 Highlands Pkwy, Ste 450
Smyrna, GA 30082
(800) YEL-4HAL

Hygenic Manufacturing
1245 Home Avenue
Akron, OH 44310
(216) 633-8460

Industiral Arts Supply
5724 W 36th Street
Minneapolis, MN 55416
(612) 920-7393

Linear Technology
1630 McCarthy Blvd
Milpitas, CA 95035
(408) 432-1900

Parts Express
340 E First Street
Dayton, OH 45402
(800) 338-0531

PC Techniques
7721 E Gray Road #204
Scottsdale, AZ 85260
(602) 483-0192

Plessey
1500 Green Hills Road
Scotts Valley, CA 95067
(408) 438-2900

Premium Parts+
PO Box 28
Whitewater, WI 53190
(800) 558-9572

Sawtek
1818 South Hwy 441
Apopka, FL 32703
(407) 886-8860

Siemens
2191 Laurelwood Road
Santa Clara, CA 95054
(408) 980-4500

Sony
9 West 57th Street, 43rd Fl
New York, NY 10019
(212) 371-5800

Texas Instruments
PO Box 809066
Dallas, TX 75380
(800) 336-5236

Trimble Navigation
585 N Mary Avenue
Sunnyvale, CA 94086
(800) TRI-MBLE

Winegard
3000 Kirkwood Street
Burlington, IA 52601
(319) 754-0600

As usual, be sure to send all your entries directly to *Synergetics*, rather than on to **Electronics Now** editorial.

Let's hear from you.

"Free Energy" Resources

I got a surprisingly high number of "free energy" enthasiasts calling and writing over our recent coverage of the heat engine basics. I was bemused by those of you using biblical quotes to disprove the thermodynamic laws.

There was one minor error in the column. Rankine's name was spelled wrong. Sorry about that.

To me, looking for any free energy sounds really dumb. Firstoff, because the odds of finding any are pitifully low. Second, because others will see you as being a few chips shy of a full board. Lastly, unlimited free energy is *not* in the least desirable in any way, shape, or form. Free energy would hasten the isoentropic heat death of the planet.

Which would be the most heinous crime against humanity imaginable.

Nearly all free energy experiments involve bad or missing labwork. Or theories that are not even wrong. Or blatant misinterpretation of the data. Or ignored hidden factors that mask what is really coming down.

Or plain old outright cons.

Quoting Carl Sagan, "Extraordinary claims all require extraordinary evidence." It is not enough to claim something is happening. Instead, you must have absolute proof which is incontrovertible and overwhelming.

Proof far above experimental noise levels. And well within the statistical bounds. And free of hidden factors. And easily and openly duplicated by anyone, anywhere, anytime.

That's what the scientific method *always* calls for.

Now, I am very much in favor of encouraging individuals to check out oddball, unpopular, or controversial technical areas on their own. That's what hardware hacking is all about. But your odds of any success should end up far higher if you stay within the guidelines dictated by the laws of physics and electronics.

It turns out there is a rather lively "free energy" industry. These include specialty booksellers, associations, conferences, and individual authors who publish books, papers, projects, and kits. Just for kicks, I thought we would gather all of these together as this month's resource sidebar.

Why? Well, first because they are there. Second, because even the free catalogs can be wondrously bizarre reading. And, finally, because many of these publications are textbook perfect examples of how *not* to do research, how *not* to do tech writing, and how *not* to desktop publish.

Let's do a quick rundown of some of the major players: Start with *High Energy Enterprises*, who offer a wide selection of topics ranging from free energy to perpetual motion to Tesla to intergalactic happy faces on Mars. These folks also run conferences. A recent spinoff here is the *National Association for New Science*, who do offer similar services and publish the *New Science News*.

A Canadian group is the *Planetary Association for Clean Energy*.

Two unique outfits are *Borderland Research* who focus on paranormal and free energy theories. They also publish their *Journal of Borderland Research*. Is this ever. Boy, a whole flock of 'em flew over that time. And *Lor'd* is now heavy into the alternate medical electronic therapies.

Or, for the "more miles per gallon" miracle carburetors, you can try *H&A*

Industries. Competing offers appear in all those fine print classifieds in *Popular Science*, *Popular Mechanics*, and their many clones.

Checking the classifieds in *Whole Earth Review* reveals *Super Science* heavy into *Orgone Energy Blankets* and *Rife Resonators*. And *Amazing Archives* on antigravity and on "300 suppressed technologies".

Nikola Tesla seems to be the center of much "free energy" research. The key problem is that Tesla was both a brilliant inventor *and* a superb con artist. Four additional resources that focus on Tesla are the *Tesla Society* (who publish *Extraordinary Science*), the *Tesla Bookstore*, the *Tesla Coil Builder's Association*, and *Resonance Research*. The latter custom builds museum-quality exhibits.

An outfit known as A.D.A.S. stocks papers including *The Final Secret of Free Energy* by T. Bearden. The key circuit Beardon describes as needed for extracting the "zero-point scalar energy from the fabric of space" has long been available as the LTC1073 by *Linear Technology*.

I find it somewhat strange that the Linear Technology engineers haven't noticed their oscilloscopes melting or all their test benches vaporizing when testing these chips.

There are several outfits offering technical kits and plans based on the "Don Britton" model of one person offering a bunch of self-designed low budget projects. The engineering on these designs ranges from impeccable on down to missing completely. Two firms here include *Consumertronics* and *Information Unlimited*.

Of course, *Lindsay Publications* is a unique source for any obscure tech books. They stock several fascinating perpetual motion titles.

I would very much like to get a complete list for all the free energy resources. So, as a third contest for this month, just tell me about any I may have missed. If possible, send me a catalog or else get me on their mailing list.

Finally, the old *Skeptical Enquirer*. Written mostly by high profile and "name brand" scientists who attempt to debunk pseudo-tech, junk science, and claims of the paranormal. Sadly, a lot of their debunkings are handled with such manic religious fervor that

they become what they are attacking. But these are still great reads.

New Tech Lit

Through *Industrial Arts Supply*, a combined catalog on industrial arts and tech education products. Included are injection molding machines, heat formers, and casting products. This one is a "must have".

The *SAW Scene* is a new and free newsletter on surface wave acoutsical devices from *Sawtek*.

From *Alpha Supply*, a fat catalog of tools and findings for jewelers and rockhounds. Plenty of obscure tools here with great hacker possibilities.

Those hard-to-find 72 pin Super Ninny game cartridge connectors are offered by *Parts Express*. Another useful source of VCR and camcorder stuff is *Premium Parts+*.

From *Texas Instruments*, some free samples of their new *Power+Arrays* low cost, high power drivers. Their triple TIPC2301 looks quite handy for converting any car alternator into a power stepper motor.

A new incandescent lamp or LED dimmer that makes use of pulse width modulation is available as the BTS 629 from *Siemens*. Cavers are sure to scoop this up for helmet lights.

A reminder that *Speleonics* is a superb labor-of-love newsletter for technical items of interest to cavers. And lots more details on all sorts of very unusual or oddball publications appears in the *Resource Bin* reprints. And, of course, in bunches of files now up on *GEnie* PSRT.

One source of lower cost digital voice technology is *Eltech*. Remote controls, security devices, and related hi-tech goodies are offered by *Home Automation Laboratories*. A pair of reasonably priced sources for sheet rubber products include *Biltrite* and *Hygenic Manufacturing*.

For the fundamentals of starting up your own technical or craft business, you might check into my *Incredible Secret Money Machine II*, available per my *Synergetics* ad.

A reminder that I have arranged for a new and faster *GEnie* signup for my PSRT RoundTable. Refer to the *Need Help?* box for details. Genie has just sharply reduced their rates and now is a really great buy.

See you there. ❖

Don Lancaster's
Hardware Hacker

September, 1993

An update to last month's free energy resource sidebar: The *International Association for New Science* newly released their 540 page proceedings from their latest *International Symposium on New Energy*. At $49.50.

Most of the major players show up here, along with bunches of historical references. All of the usual topics are covered – antigravity, Reed motors, pulsed magnetics, zero point scalar energy, homopolar generators, Tesla earth resonance, perpetual motion, element transmutation, cancer cures, alternate fusion, the whole bit.

My own personal view is that this is one fascinating and wonderously bizarre work of fiction. I do feel that many of the papers presented exude a distinct aura of outright hogwash.

On the other hand, step number one in researching any controversial topic is to find out who is doing what to whom. Even a totally absurd and "not even wrong" notion can lead to genuinely useful and innovative new concepts. Forums should exist for all controversial thought. Which makes this one definitely worth a look.

Thermoelectric review

Judging by the helpline calls lately, there seems to be a lot of interest in the solid state thermoelectric coolers now cropping up surplus. Sadly, most hackers don't pick up on the fact that there are several *very* rude surprises awaiting when they try to use these in the real world.

So, one more time: These thermo modules are *extremely* inefficient and need *extremely* good heatsinks. They are strictly limited to very low power uses. They also *demand* simple and obvious heat flux calculations which lots of hackers positively refuse to make. For most hacker uses most of the time, the *thermoelectric cooling modules simply do not work*.

Let's see why this is so.

Solid state thermoelectric modules using the *Peltier* cooling effect were developed over three decades ago and have not changed or improved one

whit since. The players change every few years in an industry that's been chronically unprofitable. One current supplier is *Melcor*. They do offer data sheets and design notes.

Figure one shows a typical heat pumping curve for the larger twenty watt module. Applying a dc current across the device causes heat to be moved from one surface to another. This module might need fifteen volts at three amps for operation.

Note that the heat pumped depends inversely on your temperature drop across the device. Yes, you can pump twenty watts of heat through a *zero* temperature difference. Or you can pump zero watts of heat across a 50 degree temperature difference. With, of course, *zero* efficiency.

More typically, you'll want to both pump heat and have a high delta-T. A normal operating point might be a 25 degree drop when pumping 10 watts.

The module data sheets carefully bury their efficiency figures for most normal operating points. Often, *three* watts of energy are required to move one. This is an EER *Energy Efficiency Rating* of a laughable 0.33. Compare this against a US air conditioner with

an EER of 12. Or a Japenese one with a superb EER of 17.

The low efficiency would not be all that bad if all of the excess heat was not generated in the wrong place at the wrong time. But what you have done when you use a TE module is *add* heat precisely where you are trying to eliminate it.

It is trivially easy to pick up more delta-T rise between your module hot side and ambient than the delta-T cooling the module is providing!

Let's use an aquarium cooler as an example. Now, there is another name for any large aquarium. It is called a *super efficient heatsink*. So, let's take our super efficient heatsink and then remove some heat from it. Because of the TE module inefficiency, we may have to add three new watts of heat for every one removed and put it into a new heatsink.

Naturally, we would not want the new heatsink to rise up as far above ambient as the aquarium goes below, or we will simply be heating up the ambient air. So, we'll shoot for an output temp rise of only a quarter the cooling drop.

Your final heatsink will have to be

20 watts of heat across 0 degrees. Efficiency is **LOW**.

10 watts of heat across 25 degrees. Efficiency is **VERY LOW**.

0 watts of heat across 50 degrees. Efficiency is **ZERO**.

Heat pumped in watts

Temperature differential in degrees C
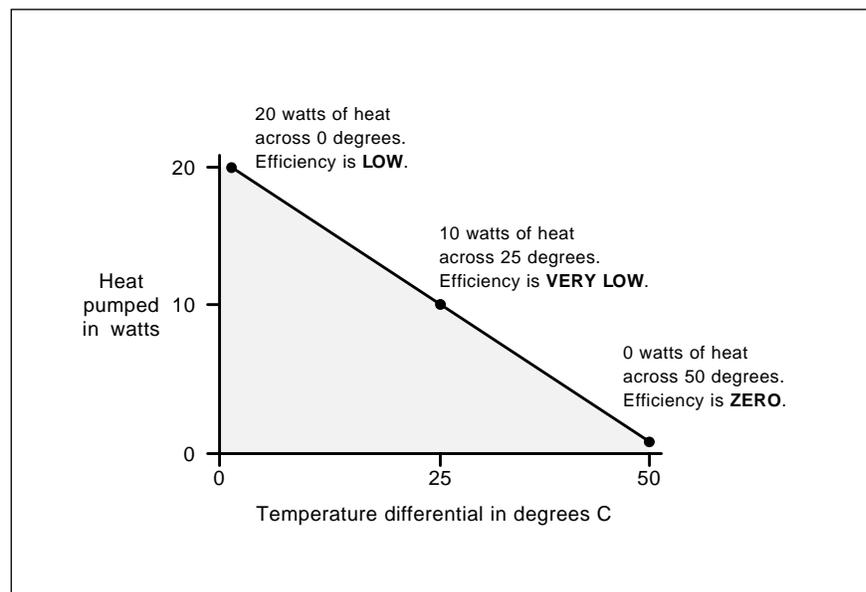
Fig. 1 – HEAT PUMPING CURVE for a larger thermoelectric module. Note that the efficiency goes down as the temperature differential increases.

1. The area to be cooled *must* be superinsulated. All avoidable sources of heat gain *must* be carefully excluded.

2. Realistic heat flux calculations and heatsink thermal impedance calculations *must* be carefully made ahead of time.

3. Current thermoelectric modules are an inappropriate solution if more than twelve watts of actual cooling are called for.

4. The rise of the module hot side temperature above ambient *must* be kept as low as possible. This rise must *never* exceed a small fraction of the total temperature drop desired.

5. Very large and extremely high quality heatsinking is a must. Use forced air cooling at the very least. Pumped water cooling may be required to achieve an acceptable efficiency.

6. Power sources *must* have very low ripple and hum, since the ripple peaks heat much worse than the troughs cool.

7. Surfaces contacting the module *must* be ultra-flat. 100% contact is essential. Thermal grease *must* always be used.

Fig. 2 – USE THESE GUIDELINES for all of your thermoelectric module designs. Otherwise, you are likely to end up heating instead of cooling!

16 times better than your aquarium! A handy way to do this is to simply use a second aquarium which is 16 times larger.

Just how much heat are we talking about here? That's what doing heat flux calculations is all about. Let's review the basics.

(A) This approximate block diagram…

(B) Generates this burst of six micropower impulses…

(C) To produce this transmitted waveform…
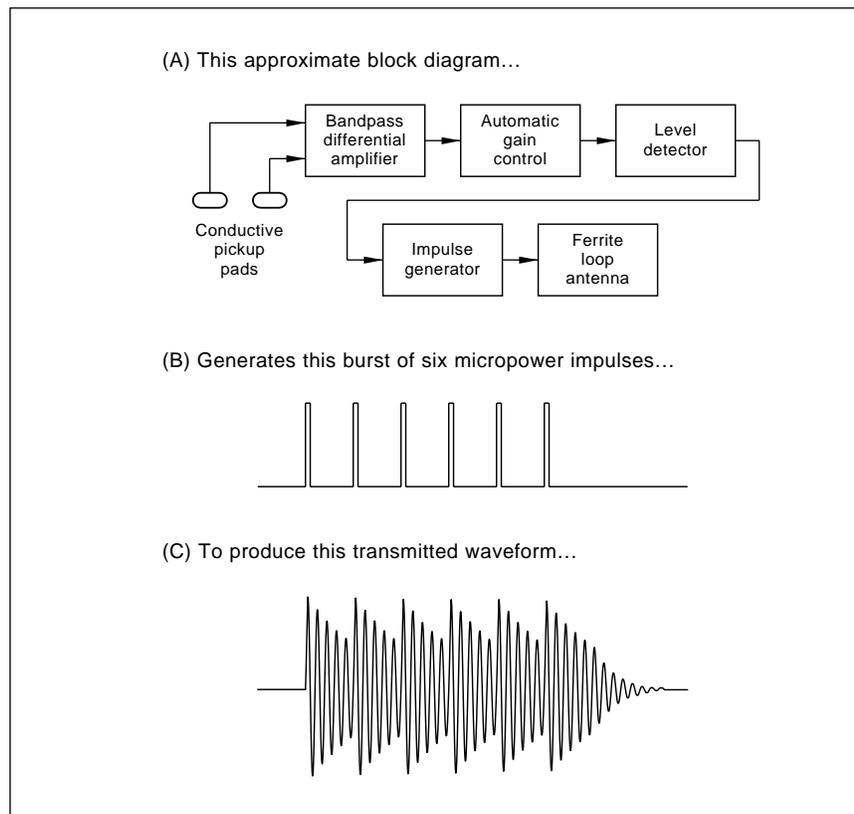
Fig. 3 – THE MYSTERY WAVEFORMS inside a typical "chest type" pulse monitor revealed. The transmitted signal approximates a 36 cycle burst of 5 kilohertz sinewaves. One burst per pulse event. What you really have here is plain old inductive coupling using an air core transformer.

The two key numbers you have to look for are your *watts of cooling required* and your *heatsink thermal impedance*. Going on back to square one, a *BTU*, or *British Thermal Unit* is the amount of energy needed to raise or lower the temperature of one pound of water by one degree F.

There are around eight pounds of water per gallon, so eight BTU's are needed to shift the temperature of a gallon of water by one degree F. A temperature change of one BTU per minute will occur when 17.58 watts of power are input.

Heat flux ends up proportional to temperature difference. For a given heatsink, you'll get twice the delta-T for twice the watts passed through. Math similar to plain old Ohm's law defines the *thermal impedance*.

A typical ordinary heatsink might have a thermal impedance of between two and ten degrees C per watt. If the thermal impedance is five degrees per watt and if you are transferring eight watts, the thermal rise will be a total of forty degrees.

To get below one degree per watt, you usually have to go to forced air cooling. To get under half a degree per watt, a pumped water cooling is often the best choice.

The key problem with solid state thermoelectric coolers is that *the heat rise of your hot side of the* TE *module above ambient can easily exceed the net cooling of the module itself!*

Ferinstance, you might have your module doing a 30 degree cooling, but your heatsink hot side might have a 40 degree rise above ambient. The net result is ten degrees of *heating*. The exact opposite of what you are trying to do.

Not to mention moving to a much less efficient point on the TE module response curve.

In the case of the aquarium, you can easily measure your heat flux. The results will depend on the surface area of the aquarium, the ambient air flow, the temperature drop required, and the amount of water present.

Temporarily remove the fish and fill the aquarium with ice water. But otherwise leave it run with the usual lights and pumps and whatever. Next, carefully measure your temperature *vs* time as the ice melts and slowly reaches room temperature. The *Radio*
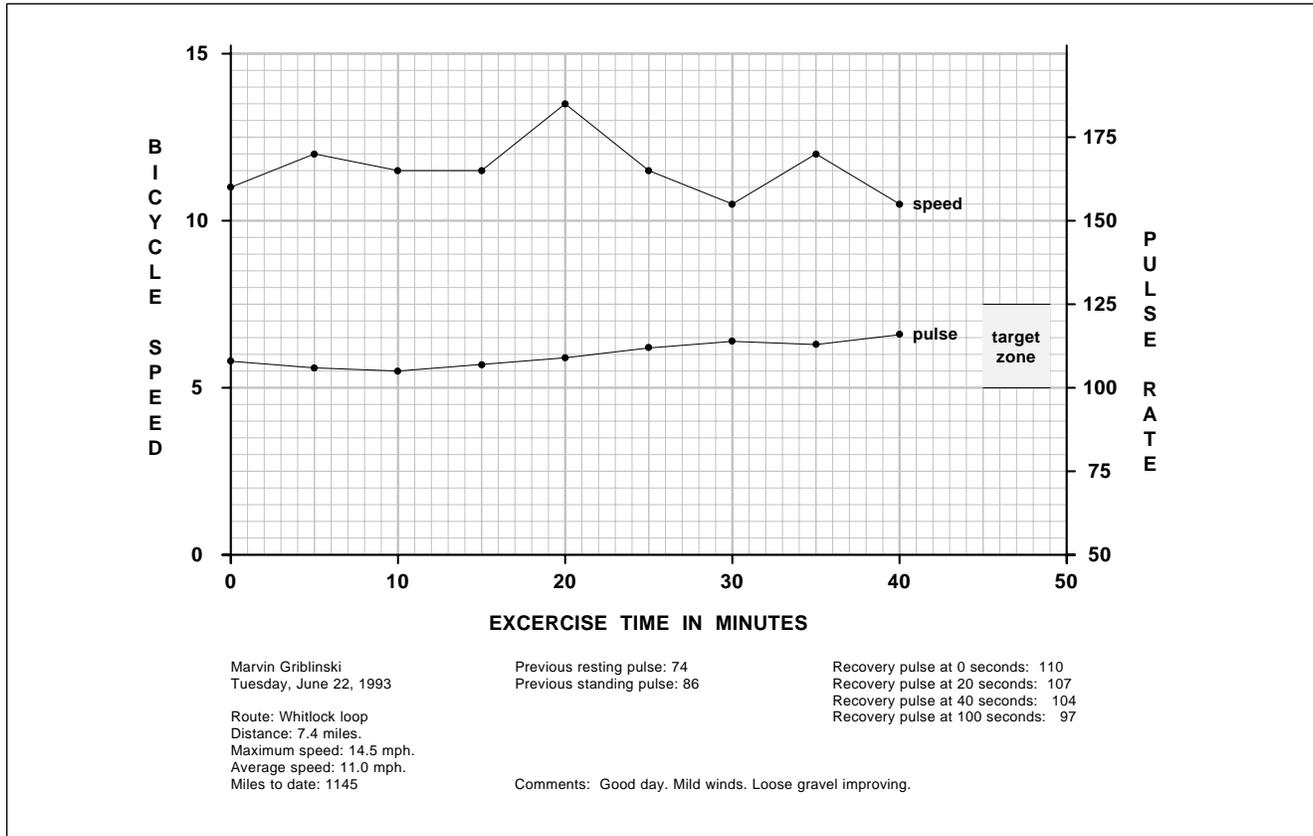
Fig. 4 – AEROBIC EXERCISE RECORD written in PostScript. Fully editible source code appears on GEnie PSRT.

Shack #277-0123 digital thermometer is ideal for this.

Then plot your temperature rise versus time on a graph. Next, find the *slope* of the warming curve *at your target temperature*, in degrees per minute. To hold the target temp, the degrees per minute cooling needed will equal the degrees per minute warming taking place.

Multiply the pounds of water times the degrees per minute of cooling needed to get the BTU's per minute required. Multiply this by 17.58 to get your cooling watts needed. Finally, multiply by some fudge factor like 1.5 for a safety margin.

The chances are the final cooling power required will be *hundreds* of times higher than what can be done using TE modules.

I haven't actually run this warming test, but I'd guess that 300 watts of cooling would not be an unreasonable value for a larger aquarium to be kept fairly cool.

And if you do burn up three watts of inefficiency for every single watt pumped, something like 1200 watts of heat will have to go out through your heatsink. With a one watt per degree C rise heatsink, the TE module hot side temperature will try to go to 1200 degrees.

Otherwise known as a fish fry.

Thirty of the twenty watt modules would be needed!

Do those new CPU thermoelectric coolers work? I'd be willing to bet that if you removed the cooler and coupled the heatsink directly to the CPU chip itself, the results would end up as good or better. Simply because you are not adding extra heat at a 3:1 premium where you don't want it.

A related story: Years ago there was this total federal solar fiasco involving a school in the rural south. This was to be a pilot demonstration project of a solar adsorption cycle cooler. The results weren't quite as good as expected, so they added a new five ton evaporative cooler to the output to improve the heatsinking to ambient air. Sure enough, the cooling then met spec.

Then someone asked this rather embarassing question: How much evaporative cooling would have been needed if the solar adsorbtion cooling was never in use at all? The answer? *Three tons!*

Using TE modules for many hacker applications can end up the same as building a bonfire inside an icebox.

Are there any places at all where TE modules can be used? Certainly. *If* you have carefully made your heat flux measurements. And *if* you are only moving tiny amounts of heat out of a superinsulated region. And *if* you are dumping into a big heatsink with an unusually low delta-T.

You also have to use super smooth surfaces, proper thermal grease, and avoid *all* ripple in your power supply. The tiniest amount of ripple will foul things up because the ripple troughs heat six times better than the peaks will cool.

Naturally, trying to freeze ice is beyond the pale.

Figure two shows some guidelines for proper use of TE modules.

These modules can be a sure fire winner for most science fairs, where you can easily feel all the heat going from your thumb to your finger. Even with a single alkaline or lithium "D" cell. They are also quite useful for chilled mirror dewpoint instruments. And handy in high vacuum aps where moving parts are a no-no.

TE modules are great for cooling microscope stages, special astronomy instruments, and infrared detectors. But the modules don't seem usable in satellite dishes because the gain drops faster than noise figure improves.

What are the practical alternates to TE modules? Small compressors are not that big a deal. Obvious sources are drinking fountains, refrigerators, icemakers, and reworked auto air conditioners. One source of info on these is *HVAC Contractor.* A drinking fountain compressor will only need 60 watts of new energy to pump 300.

But the neatest substitutes for TE modules are called *vortex coolers.*

This second cousin to a perpetual motion machine seems to blatantly violate thermodynamic laws. They do not, of course.

A vortex cooler is simply a magic Tee-shaped pipe. No moving parts at all. You blow ordinary air into the middle, and hot air comes out one end and cold air out the other. Down to -40 Farenheit temperatures and tons of cooling.

Leading suppliers include *Vortec* and *Exair.* Some important uses are for electronic cooling and stopping needle breakage on industrial sewing machines.

I would guess that a vortex CPU cooler could be done very simply and easily. And would work ridiculously better than a TE module. As far as I know, nobody has even tried.

Some pulse monitor discoveries

Warnings: Do not ever modify an EKG-type pulse monitor any way for any reason! Do not ever attempt to build up your own units of this type! What follows is not in any manner to be construed as medical advice.

I've been developing some aerobic exercise software for a client. Using PostScript, of course. Which I have found to be the greatest universal hacker's language anywhere ever. I

have also been looking closely at the pulse monitors and have found some fascinating new electronic concepts that you might wish to expand upon one way or another. These concepts should apply beautifully to short haul telemetry apps.

But *please* be careful to heed all the above warnings.

One way to deal with exercise, of course, is to get yourself a corned beef and pork fat sandwich, add a helping of Eggs Benedict, and chow down until the urge goes away. There are others who do feel that sustained exercise programs provide positive benefits towards longevity, physical conditioning, well being, and for use as medical therapy.

The harder you exercise, the higher your heart rate. An *aerobic* (or "with oxygen") exercise attempts to set up a *target zone* elevated pulse rate over a fairly long time period. Say half an hour to an hour for cycling, group aerobics, swimming, jogging, or fast walking.

A conditioning target zone might be 60 to 75 percent of the maximum heart rate. This max rate in turn can depend upon sex, age, and upon the advice of your physician or aerobics instructor. Ferinstance a 30 year old male might have a target zone of 114 to 142 beats per minute.

The old "thumb and stopwatch" method of measuring pulse rate has some obvious problems. Not the least of which is that it woefully disrupts the program in progress. There are instead two popular new methods to measure pulse, the *plethsymograph*, and the *EKG sensor.*

The plethsymograph is based on finger or toe capillaries expanding and contracting with each pulse beat. Shine infrared light on through your finger, and its transmission will vary with your pulse. Opacity depends on how much blood is present. You can then amplify, condition, and digitally average these variations to extract the current pulse rate. Cheaply, simply, and noninvasively.

Infrared plethsymographs are easy to find, even as the $19.95 specials at K-mart. Unfortunately, many of these simply do not operate properly in aerobic exercise situations. The main problem involves *motion artifacts.* Any relative motion between sensor

and finger will give a false output and highly erratic results. Infuriatingly so. To the point of being useless.

Better yet, there are *EKG-style* or "chest type" monitors that directly measure the electrical activity of the heart. These usually are offered in two pieces, a small chest strap, and a stopwatch-type display that is either worn on your wrist or mounted on the bicycle or other exercise gear.

The cost of these systems is often in the $70 to $200 range. But they are totally free of motion artifacts. And you can *instantly* check your pulse at any time during the activity. Simply glance at the display. These also offer settable alarms that trip if you wander outside your target zone. Clock and stopwatch functions are included.

One typical unit is the *Edge Heart Rate Monitor* distributed by *Polar* and stocked by such yuppy outdoor stores as *REI*. I did try this one in combination with a *Trek* bicycling computer. A second brand is *Favor*. You could also get a combo monitor and bike computer in one unit, such as the *Vetta* HR-1000 also offered by *REI*. At $95 list.

How do they work?

The chest unit is totally sealed and has an internal battery. In normal use, it gets replaced every year or two. The internal battery is purposely *not* replaceable to guarantee that the unit remains unmodifiable. There are very stringent regulations over anything electronic which directly attaches to your chest.

Obviously, the chest unit acts as a transmitter and the wrist unit serves as a receiver. The effective range is typically four feet or so.

But what gets transmitted how? The answer to this one is yet another stunningly beautiful example of our ongoing quest for elegant simplicity.

What we really have here is more short haul telemetry. But one that has to remain totally sealed, be compact and lightweight, reliably run forever under micropower, and literally be a throwaway item. At five bucks max manufacturing cost.

The secret is a plain old inductive coupling. Figure three shows the secret waveforms involved. What you really have here is a 5 kilohertz air core transformer, with the primary in

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NAMES AND NUMBERS

Antique Radio Laboratories
Rt 1, Box 41
Cutler, IN 46920
(317) 268-2214

Exair
1250 Century Circle North
Cincinnati, OH 45246
(513) 671-3322

GEnie
401 N Washington Street
Rockville, MD 20850
(800) 638-9636

Heath Nostalgia
4320 196th SW, Ste B-111
Lynnwood, WA 98036

HVAC Prod News/Contractor
1350 East Touhy Avenue
Des Plaines, IL 60018
(708) 635-8800

Intl Assn for New Science
1304 S College Avenue
Fort Collins, CO 80524
(303) 482-3731

Linear Technology
1630 McCarthy Blvd
Milpitas, CA 95035
(408) 432-1900

Maxim
120 San Gabriel Drive
Sunnyvale, CA 94086
(408) 737-7600

Melcor
1040 Spruce Street
Trenton, NJ 08648
(609) 393-4178

Mondo-tronics
524 San Anselmo Avenue #107
San Anselmo, CA 94960
(415) 455-9330

Oughtred Society
8338 Colombard Court
San Jose, CA 95135
(408) 238-8082

Resources UN-LTD
8030 South Willow Street
Manchester, NH 03103
(603) 668-2499

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

TriQuint Semiconductor
3625A SW Murray Blvd
Beaverton, OR 97005
(503) 644-3535

Vortec
10125 Carver Road
Cincinnati, OH 45242
(800) 441-7475

Wireless Design & Development
Box 650
Morris Plains, NJ 07950
(201) 292-5100

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the chest unit and the secondary in the wrist or handlebar receiver. Each pulse gets converted into a 36 cycle burst of 5 kilohertz sinewaves.

You can very easily monitor these waveforms. Just take any old coil, such as the fifty foot roll of *Radio Shack* hookup wire. Add an iron core, such as a handy pair or pliers. Center the coil near the chest unit. And then watch the results on your scope.

A pair of conductive pads pick up the EKG signals on either side. These microvolt-sized signals are strongly amplified in a bandpass amplifier. There is probably some type of AGC automatic gain loop to standardize the output levels. Then, a comparator of some sort derives a digital output for each pulse event.

Each pulse event then generates a series of six digital impulses. Each impulse is around 80 microseconds wide and has an interpulse spacing of one millisecond. For a one kilohertz repetition rate.

If very low power is your goal, you cannot use any kind of linear amp for your transmitter. Instead, the antenna is simply a 5 kilohertz resonant coil. The plots found in my *Active Filter Cookbook* tell us the Q of this coil is around 20 or so.

To transmit a signal, the resonant antenna coil gets whapped *once every five cycles*. The high Q of the coil fills in during the intermediate cycles. If you do look at your scope display very carefully, you will observe the modest exponential decay of all the intermediate cycles between impulse whappings. The long rundown time after the last whapping is also quite obvious.

The spacing of the impulses can be tightly controlled. Which elegantly minimizes any need for super precise or ultra stable antenna tuning.

Only the bandpass amplifier draws continuous current. Both *Maxim* and *Linear Technology* do make suitable amps that consume only microamps.

In absence of any pulse input, there is no output and no transmitted signal sent. Even when a burst gets sent, the duty cycle to generate the burst is 10:1 and the duty cycle of the burst itself is typically 80:1 or so.

The average current ends up quite low. Very elegant.

X-raying the unit revealed a few surprises. A large lithium coin cell is used. The antenna is a ferrite rod, long axis horizontal that is apparently tuned by unwrapping a few turns. It gets resonated by a polystyrene cap. A 14 pin integrated circuit drives the antenna. This is probably a plain old grunt CMOS quad gate.

The majority of the input circuitry is discrete and consists of nine SOT transistors and 24 assorted resistors and caps. Several special techniques are required for proper noise rejection and ultra low power operation.

The receiver is just a resonant coil and a bandpass amplifier that inputs

into typical micro current stopwatch circuitry. This amplifier apparently shuts itself down in the absence of any transmitted signals. The receiver battery can get replaced and lasts a year or more. An averaging algorithm is used to smooth out the results for a stable display.

A sample printout for a routine exercise session is shown in figure four. The complete PostScript code to custom run these on your favorite word processor appears on *GEnie* PSRT as #751 EXERCISE.GPS.

You could build up an automatic data acquisition system to automate the whole process. But it is simpler and cheaper just to use a one-hand cassette recorder every five minutes and talk the speed and pulse rate to it. With practice, it takes less than two minutes to transfer the data.

I've gathered several places to go for more info on pulse monitors into our resource sidebar for this month. *Creative Health Products* offer a free comparison guide for many of the more popular monitors.

This month's contests

Let us have a bunch of different contests this month. Show me some other uses for inductive coupling in short haul telemetry. Or find me the actual schematic of some EKG-type pulse monitor. Or find a hackable source of pulse monitor chips.

Which should be ideal for one of my *isopod* power line monitors.

Or run the aquarium ice warming test. Or show me a genuinely useful hacker ap for TE modules that works in the real world. Or show me some other off-the-wall uses of PostScript for new data-to-plot applications.

There'll be all the usual *Incredible Secret Money Machine II* book prizes along with an all-expense paid (FOB Thatcher, AZ) *tinaja quest* for two going to the best of all.

As usual, be sure to send all your entries directly to *Synergetics*, rather than on to **Electronics Now** editorial.

Let's hear from you.

New tech lit

Up the Infinite Corridor is a new book on the history of engineering at *MIT* by Fred Hapgood. A really good read. But by far the best part is Fred's revival of a very ancient seven-word

def of what engineering is all about: *A sense for the fitness of things.*

That says it all.

Lots of night vision electronics and surplus infrared viewers are available from *Resources Unlimited*. They have a free brochure waiting for you.

A new $9.95 book on the history of *Heathkit* from *Heath Nostalgia*.

Antique Radio Laboratories has a free catalog on all their products for radio restoration buffs. Included are custom pins, adaptors, bases, and coil forms. They also stock manuals for older test equipment.

The *Oughtred Society* exists for the collectors of traditional slide rules and related calculating instruments. Named for the seventeenth century slide rule inventor. $20 for meetings and classified ads.

Motorless Motion is a project book from *Mondo-tronics* on working with the shape memory "muscle wires" for robotics and similar uses. Included are fifteen easy-to-build projects and layout templates. $18 for the book; $29 for book and wires.

From *TriQuint Semiconductor*, a new *Data Communication Products* data book. Mostly on new microwave integrated circuits such as low noise amplifiers, mixers, downconverters, and AGC stages.

Wireless Design & Development is a new trade journal on new products for the emerging personal microwave communication services. Free subs are offered to industry insiders.

As we've seen a number of times in past columns, any hardware hacker involvement with the patent system is virtually certain to end up a net loss of time, energy, money, and sanity. Mostly because of all the outrageous popular mythology which surrounds patents and patenting. A mythology that is almost always dead wrong.

I have put together my new *Case Against Patents* reprint package that includes several hundred pages of proven alternates to patenting. A big directory of hundreds of the inventor organizations is included. Check my nearby *Synergetics* ad for more info.

A reminder that I have arranged for a new and faster *GEnie* signup for my PSRT RoundTable. Refer to the *Need Help?* box for full details. Genie has recently sharply reduced their rates and now is a really great buy. ❖

Don Lancaster's
Hardware Hacker

October, 1993

Contacting and intelligently communicating with those in the know can often end up a serious hardware hacking problem. So can finding out who has written what, when, and where.

But this month, there's been a pair of really big happenings that make two crucial hacker resources cheaper and far easier to use…

Usenet

The *Usenet* is often called *Anarchy 101*. This is a giant national computer network which connects virtually *all* schools and universities, all research outfits, most high tech firms, and the larger government agencies. Unlike typical BBS systems, there's no sysop as such. Nor any central repository.

For instance, mere *minutes* after that Fermat's last theorem had been solved, the proof was spreading like wildfire on Usenet. I've uploaded a condensed proof outline to my *GEnie* PSRT as #753 FERMAT.TXT. We also go out of our way to abstract most of Usenet's PostScript traffic.

Nearly all insiders in any technical field have Usenet addresses. But the trouble has been that Usenet access had to be done through a sponsoring organization. And becoming a Usenet sponsor involves big bucks. So access by individuals was by invitation only.

GEnie has recently opened a new Usenet email gateway. There is no surcharge for this access; its just part of GEnie's low hourly rate.

Let's say someone has a Usenet address of…

clyde@bark.newco.org

To email them from GEnie…

clyde@bark.newco.org@INET#

That *@INET#* trailer does the link up for you. Similarly, say you want to reach me through my *SYNERGETICS* GEnie email address. Use a…

Synergetics@GEnie.GEIS.com

…as a Usenet address. For anyone else, just add the…

…@GEnie.GEIS.com

trailer to the *GEnie* email address.

Because my PSRT works on shared information, answers for a technical email question get directly posted to the PSRT RoundTable. A two hour response time is typical.

Oh, yeah. There's a convention in any Usenet message. One that *must* be strictly and rigorously obeyed at all times. *Be verbose!* A simple "yes" or "no" answer will *never* do. These are mostly academic UNIX folks you are dealing with here.

Instead, you'll first describe every wire that your message travels over. Then you give your entire genealogy on back to your great grandmother's cousin twice removed.

Then you quote verbatim anything

and everything anyone else has ever said on the subject, back to day one.

Then you say your "yes" or "no" in as oblique a manner as possible. Then say something that is supposed to be funny. Then quote something long and somewhat literate that Chekhov would find totally obtuse.

Finally, issue a disclaimer that a gaggle of Byzantine lawyers would find bulletproof. Then say goodbye.

Aim for a bare minimum of half a megabyte per yes-no email message response. Otherwise "they" will spot you as a rank outsider.

Dialog

I've long recommended the *Dialog Information Service*. For Dialog can give you instant answers to *any* tech question in *any* field of study. From

Book Review Index –	Two million reviews of books and periodicals.
Books in Print –	Everything published by author, subject, title.
CA Search –	Ten million entry chemisty data base.
Career Placement –	Professional employment resumes.
Compendex –	4500 engineering and technology journals.
Computer Database –	Full text of most computer magazines.
Conference Papers –	Offers 100,000 scientific and technical papers.
Current Contents –	Contents of leading scientific and tech jounals.
Derwent World Patents –	Has six million worldwide patents.
Dialog Quotes –	Stock and option prices, delayed 20 minutes.
Dissertation Abstracts –	All advanced degree dissertations since 1861.
Electric Power Database –	Commercial power R & D projects.
Encyclopedia of Associations –	Lists 81,000 organizations worldwide.
Energy Technology –	Database for the US Department of energy.
Federal Register –	Everything by the government printing office.
Foundation Directory –	Lists 32,500 organizations that give money away.
Geobase –	Geography, geology, and ecology data base.
INSPEC –	Physics, electronics, and computing data base.
Magazine Index –	Covers 500 popular magzazines.
Mathsci –	Abstracts for math, computers, and statistics.
Microcomputer Index –	Articles from 50 microcomputer journals.
NTIS –	National technical information service database.
Peterson's College Database –	Complete guide to US colleges.
Publisher's and Distributers –	Who publishes what, when, and where.
Scisearch –	Multidisciplinary index to science and technology.
Thomas Register –	Directory of all manufacturers of everything.
Ulricht's Periodicals –	Lists 100,000 publications in all fields.
U.S. Patent Abstracts –	A complete patent repository.

Fig. 1 – THE DIALOG INFORMATION SERVICE is newly available on a low cost cash-and-carry basis. Of their 400+ data bases, I use these the most.

	–0	–1	–2	–3	–4	–5	–6	–7	–8	–9	–A	–B	–C	–D	–E	–F
LOWER HEX VALUE																
0–	0 NUL \000	1 SOH \001	2 STX \002	3 ETX \003	4 EOT \004	5 ENQ \005	6 ACK \006	7 BEL \007	8 BS \010	9 HT \011	10 LF \012	11 VT \013	12 FF \014	13 CR \015	14 SO \016	15 SI \017
1–	16 DLE \020	17 DC1 \021	18 DC2 \022	19 DC3 \023	20 DC4 \024	21 NAK \025	22 SYN \026	23 ETB \027	24 CAN \030	25 EM \031	26 SUB \032	27 ESC \033	28 FS \034	29 GS \035	30 RS \036	31 US \037
2–	32 SP \040	33 ! \041	34 " \042	35 # \043	36 $ \044	37 % \045	38 & \046	39 ' \047	40 (\050	41) \051	42 * \052	43 + \053	44 , \054	45 - \055	46 . \056	47 / \057
3–	48 0 \060	49 1 \061	50 2 \062	51 3 \063	52 4 \064	53 5 \065	54 6 \066	55 7 \067	56 8 \070	57 9 \071	58 : \072	59 ; \073	60 < \074	61 = \075	62 > \076	63 ? \077
4–	64 @ \100	65 A \101	66 B \102	67 C \103	68 D \104	69 E \105	70 F \106	71 G \107	72 H \110	73 I \111	74 J \112	75 K \113	76 L \114	77 M \115	78 N \116	79 O \117
5–	80 P \120	81 Q \121	82 R \122	83 S \123	84 T \124	85 U \125	86 V \126	87 W \127	88 X \130	89 Y \131	90 Z \132	91 [\133	92 \ \134	93] \135	94 ^ \136	95 _ \137
6–	96 ` \140	97 a \141	98 b \142	99 c \143	100 d \144	101 e \145	102 f \146	103 g \147	104 h \150	105 i \151	106 j \152	107 k \153	108 l \154	109 m \155	110 n \156	111 o \157
7–	112 p \160	113 q \161	114 r \162	115 s \163	116 t \164	117 u \165	118 v \166	119 w \167	120 x \170	121 y \171	122 z \172	123 { \173	124	\174	125 } \175	126 ~ \176	127 DEL \177
8–	128 NUL \200	129 SOH \201	130 STX \202	131 ETX \203	132 EOT \204	133 ENQ \205	134 ACK \206	135 BEL \207	136 BS \210	137 HT \211	138 LF \212	139 VT \213	140 FF \214	141 CR \215	142 SO \216	143 SI \217
9–	144 DLE \220	145 DC1 \221	146 DC2 \222	147 DC3 \223	148 DC4 \224	149 NAK \225	150 SYN \226	151 ETB \227	152 CAN \230	153 EM \231	154 SUB \232	155 ESC \233	156 FS \234	157 GS \235	158 RS \236	159 US \237
A–	160 SP \240	161 ! \241	162 " \242	163 # \243	164 $ \244	165 % \245	166 & \246	167 ' \247	168 (\250	169) \251	170 * \252	171 + \253	172 , \254	173 - \255	174 . \256	175 / \257
B–	176 0 \260	177 1 \261	178 2 \262	179 3 \263	180 4 \264	181 5 \265	182 6 \266	183 7 \267	184 8 \270	185 9 \271	186 : \272	187 ; \273	188 < \274	189 = \275	190 > \276	191 ? \277
C–	192 @ \300	193 A \301	194 B \302	195 C \303	196 D \304	197 E \305	198 F \306	199 G \307	200 H \310	201 I \311	202 J \312	203 K \313	204 L \314	205 M \315	206 N \316	207 O \317
D–	208 P \320	209 Q \321	210 R \322	211 S \323	212 T \324	213 U \325	214 V \326	215 W \327	216 X \330	217 Y \331	218 Z \332	219 [\333	220 \ \334	221] \335	222 ^ \336	223 _ \337
E–	224 ` \340	225 a \341	226 b \342	227 c \343	228 d \344	229 e \345	230 f \346	231 g \347	232 h \350	233 i \351	234 j \352	235 k \353	236 l \354	237 m \355	238 n \356	239 o \357
F–	240 p \360	241 q \361	242 r \362	243 s \363	244 t \364	245 u \365	246 v \366	247 w \367	248 x \370	249 y \371	250 z \372	251 { \373	252	\374	253 } \375	254 ~ \376	255 DEL \377

(left side label: UPPER HEX VALUE)

Fig. 2 – THE ASCII CHARACTER CODE. Since ASCII is really a seven bit code, it repeats twice in 8-bit space. The "high ASCII" area can alternately be unused, a different character set, graphic plotting commands, internal machine flags, or other symbols. Hex, decimal and octal values are shown.

anywhere. At any time. Last count, they had some 300,000,000 citations in stock. All as abstracts and many in full text. In 400 major data bases.

Even paying their traditional $2 per minute rate, I felt Dialog had been by far the fastest, cheapest, and the most reliable way I have ever found to do research.

Dialog also offered a quarter price late evening service. But you had to subscribe to this on your own. And precious minutes could easily gobble up if you were not extremely careful with your keystrokes. And if things hung up, so did your bill.

Dialog has now turned their entire afterhours marketing to *CompuServe*. Who in turn has made it available to *GEnie*. Type *DIALOG* for access.

The really big breakthrough here is that there are no more by-the-minute Dialog charges. Instead, the setup is

strictly cash and carry. A la carte. And with sharply reduced prices.

A search will typically cost you $2.50 if you find something and $1.50 if you don't. The abstracts, in lots of ten, can cost you a total of $3. That's *thirty cents* per citation or abstract! Some fancier searches cost more.

There's also a *supersearch* feature where a few data bases can be looked into at once. Plus hard copies. Plus CD ROM access. And more.

I've tried to list a few of the more hacker useful Dialog data bases in figure one. I guess I tend to use their INSPEC data base from the IEEE a lot. This one is strong in electronics, computers, and physics. Two similar bases are *MathSci* and *Compendex*.

But do not forget all the every day stuff. Like *Books in Print*, *Ulricht's Periodicals*, the *Encyclopedia of Associations*, and the *Thomas Registry*.

Data Transmission and Compression

I've recently found some new ways to do data compression. Fast, simple, and cheap. So, I thought we might go over the fundamentals here…

Your unit of data measure is the eight bit *byte*. As many bytes as are needed get combined to create a total message, image, program, FAX page, song, video field, or whatever.

A byte may be sent all bits at once in *parallel* form. Out a parallel port or through a SCSI interface. Or a byte may be sent in *serial* form, one bit at a time. Typically over any serial port, *AppleTalk*, *Ethernet*, or MIDI. *UART* hardware or *SCC* software converts from parallel to serial and back.

Any 8-bit byte has got 256 possible states. If all of these states are needed for the data itself, you are said to be in a *binary* format. If, instead, you are mostly interested in sending out text info as letters and numbers, you are in an *ASCII* format.

The *ASCII* code appears in figure two. ASCII code was originally only *seven* bits long and corresponded to 128 possible states. 32 of these were reserved mostly for your upper case alphabet. Another 32 for your lower case alphabet. Yet another 32 got set aside for numbers and punctuation. And a final 32 for "invisible" *control characters* such as linefeeds, carriage returns, bells, the end-of-file markers, tabs, or backspaces.

To make ASCII into an 8-bit code, it is simply repeated twice. Once with the most MSB significant bit cleared to zero and called *low ASCII*. And once with the MSB set to a one and called *high ASCII*. Sometimes only low ASCII actually gets used. Other times, the high ASCII area might be reserved for an *alternate character set*, for *graphics commands*, or for *extensions* for oddball characters.

Gaining Transparency

There is a thorny problem in using *ASCII* comm for data transmission. The channel is often *non-transparent* in which certain characters (such as carriage returns) are used for system purposes. Nearly all standard serial comm is non-transparent.

Should a random byte in an image have the same code as an end-of-file

or other reserved character, you may end up in deep trouble.

Instead, the newer and better data comm systems are totally *transparent* and do not place any restrictions on the meaning that any byte can have. Examples of transparent data comm are *AppleTalk*, *SCSI*, and *EtherNet*.

Many older comm systems allow only non-transparent data. Which can mean you'll have to pull some sneaky tricks to send transparent data over them. We call these *transparancy schemes*. Per figure three.

Any trick that makes 96 printing characters look like 256 unrestricted and transparent binary codes is pretty near guaranteed to make your code longer. But these tricks do let you use older and standard comm.

One simple method is to use some *character substitution*. Here you use an escape character or a reverse slash to let you change the meaning of a single character. You could also use an *octal notation* where any problem characters get replaced with, say, a reverse slash and the octal code of the problem characters.

Since the octal codes are all digits from 0-7, these can easily be routed over any non-transparent channel as print-only characters. Ferinstance, a \267 should print out as a "•" bullet in many *PostScript* systems.

Yet another trick is to temporarily make the comm channel transparent. This is the way that XMODEM and its improved offspring lets you upload full binary data to BBS systems or over email. PostScript uses its *binary encodings* in a similar scheme. Total cooperation of sender, sendee, and a comm channel is manditory.

A more general solution is called *hex format*. When in hex format, each binary byte gets broken down into a high 4-bit sub-byte plus a low 4-bit sub-byte. Each sub-byte should have only sixteen possible values. Thus, it could be coded as the digits 0-9 and the letters A-F and then sent out as printing characters. For instance, the letter A is ASCII coded as $61 or hex coded as $4641.

Hex format is easy and simple. Its obvious penalty is that it *doubles* the number of characters stored or sent. Everything takes twice as much room and twice as long to send.

A more subtle route is *ASCII-85*. In

Escape codes—	Reserves another character such as an escape or a "\". This "breakout" allows single problem characters to be sent as two non-problem ones.
Octal definitions—	Replaces problem characters as they occur with their four byte octal equivalent. Can become ungainly if used too often.
XMODEM comm—	Temporarily disables all special characters long enough for a fixed number of binary bytes to be sent. A standard for BBS uploads.
Hex-ASCII pairs—	Each binary byte is converted into a hex pair of printing ASCII characters. Doubles file size and transmission times.
ASCII-85 coding—	Each group of four binary bytes is converted into a new group of five print-only ASCII characters. Increases file size by 20 percent.
True transparency—	The channel is replaced with a better one that has no character reservations. Such as SCSI, EtherNet, AppleTalk, or other LAN systems.

Fig. 3 – SOME TRANSPARENCY SCHEMES that let you send unrestricted binary data over a comm channel that reserves one or more ASCII codes.

Run length coding—	Replaces identical repeats with which byte to repeat how often. Used for black and white font bitmaps. Otherwise limited. Lossless.
FAX compression—	A variation on run length encoding for business letters and other "large white area" uses. Also known as the CCITT format. Lossless.
LZW compression—	The standard used for disk compaction. Offers a 2:1 to 3:1 reduction of most data forms. Noise sensitive because of low redundancy. Lossless.
DCT compression—	Uses the Discrete Cosine Transform to offer lots of compression for images and still video. Has "tiling" artifacts. Lossy.
JPEG and MPEG—	JPEG is just the most popular form of the DCT. MPEG adds motion estimation and differencing for movies and full motion video. Lossy.
Wavelets—	An improvement on DCT that has fewer artifacts and computes faster with simpler hardware and fewer tiling artifacts. Lossy.
Fractal math—	Front end intensive method that offers dramatic compression ratios of 1000:1 and beyond. Best for CD ROM image distribution. Lossy.
PostScript—	A general purpose computing language that uses extremely sparse data sets. Can greatly reduce the size of all graphic data. Lossless.

Fig. 4 – HERE IS A SUMMARY of most of the more popular data compression schemes in use today. All are fairly easy to explore on your own.

MAGIC RESOURCES

Biscayne Magic
1680 NE 123rd Street
North Miami, FL 33181
(305) 891-7224

Louis Tannen, Inc
6 West 32nd Street
New York, NY 10001
(212) 239-8383

Collector's Workshop
Rt 1, Box 113A
Middleburg, VA 22117
(703) 687-6476

Magic, Inc
5082 Lincoln Avenue
Chicago, IL 60625
(312) 334-2855

Cosmar Magic
6765 El Banquero Place
San Diego, CA 92119
(619) 287-3706

Magical Moments
1265 University Drive
Coral Springs, FL 33071
(305) 755-8586

Fantasio Magic Products
1002 Country Club Prado
Coral Gables, FL 33134
(305) 264-3321

Owen Magic Supreme
734 N McKeever Avenue
Azusa, CA 91702
(818) 969-4519

Flosso/Hornmann Magic Shop
45 West 34th Street #607
New York, NY 10001
(212) 279-6079

Patry Magic Productions
62 Washington Manor
West Haven, CT 06516
(203) 932-9586

Guaranteed Magic
27 Bright Road
Hatboro, PA 19040
(215) 672-3344

Society of American Magicians
PO Box 510260
St Louis, MO 63151
(314) 846-5659

Hank Lee's Magic Factory
PO Box 789
Medford, MA 02155
(617) 482-8749

Stevens Magic Emporium
3238 East Douglas
Wichita, KS 67208
(316) 683-9582

ASCII-85, you group all your binary bytes by fours and let each group of *four* binary bytes be sent as a group of *five* printing characters. Only the printing characters from @ through *u* are needed. In essence, you are using a base-85 numbering system.

ASCII-85 sounds horrible. And it looks even worse on screen. But it is fairly simple to do and offers only a 20 percent transmission penalty for a full transparency.

Fundamentals of Compression

You use *data compression* when you want to shorten a message. So it will store in less space, send in less time, or transmit over some narrower bandwidth. There are two penalties for data compression use. One is that time and effort is needed to compress and uncompress. The second is that a compressed message inherently has less redundancy. Any errors made on compressed data are likely to do bad damage, some of it unfixable.

A third "feature" of compression is that your information will no longer be human readable.

There are many different types of data compression which are popular today. Each one has its strengths and weaknesses. Each one will work very well for its intended use. And will perform poorly (even expanding!) for other uses. Some compression schemes appear in figure four.

Any data compression scheme is *lossless* if you could always get back *exactly* what you started out with. Obviously, electronic funds transfer and computer programs must pick a lossless compression. A compression scheme is *lossy* if you only get back roughly what you started with.

Ferinstance, that tapioca pudding scene in *Godzilla versus the Night Nurses*: Your average couch potato won't spot a misplaced pixel or two.

Lossy data compression schemes can offer much higher compression ratios with a selected quality tradeoff. This is especially important in full motion video or sending HDTV over a limited channel bandwidth.

Let's try to capture the flavor of a few compression schemes…

Run length encoding– Run length encoding often works best with font bitmaps and monochrome graphics. It is lossless and is especially good on data having long repeats of identical characters. What happens is a string of identical characters gets replaced with codes for "repeat this character this many times".

FAX compression– This one is also called CCITT format and is really a variation on the run length encoding. Also lossless. It is useful for sending monochrome documents with lots of white space. Such as business letters.

This FAX encoding is in general a rather poor performer for other data types. See ap note #5115 from *Adobe Systems* for direct comparison of all major compression schemes. The title is *Supporting Data Compression in PostScript level II*.

LZW compression– The standard used for disk compaction. Short for *Lempel-Ziv-Welch* . A totally lossless scheme that usually offers a 2:1 to 3:1 compression. This is error sensitive since redundancy is removed.

DCT compression– Shorthand for the *Direct Cosine Transform*. This is lossy but gives high compression for pictures and still video images. High quality compressions beyond 10:1 are typical. You can go beyond 30:1 with a modest loss of image quality. Tends towards objectional tiling artifacts.

JPEG and MPEG– JPEG is simply another name for the most popular version of the DCT, as is used by the *Joint Photographic Experts Group*. It is often best for still images that stand alone. MPEG by the *Motion Pictures Expert Group* is an extension of JPEG that allows significant squashing of full motion video and HDTV. It does this by overlaying *differencing* and *motion estimation*.

The MPEG results are impressive and should lead to full length videos on CD-ROM and sending HDTV over standard tv broadcast channels.

Wavelet compression– This is a stunning improvement over the DCT that eliminates many visual artifacts, codes more compactly, offers higher compression, and can execute faster. One champion of this new technology is *Aware*. These folks do have lots of reprints and ap notes available. Plus useful hardware and software.

Fractal compression– The fractal compression is a unique and totally maverick new approach. For certain images, it offers compressions in the 1000:1 to 10,000:1 range. While a lot of front end effort is needed to squash an image, ordinary software can be used to quickly rebuild all the images. Even as animation. This scheme gets particularly useful when placing scads of stand-alone visual images on CD-ROM. The leader here is *Iterated Systems*.

See FRACTFERN.PS for a classic example.

PostScript– Few people realize that the PostScript language itself can be a uniquely powerful data compressor. This happens because of the sparse data sets used to create all PostScript page descriptions.

For instance, a scanned logo might need half a meg of file space done in those primitive "cuneiform and clay tablet" coding schemes used by early PC and Mac graphic programs. A far higher quality and faster executing version of the same logo can often be done in raw PostScript in as little as a few hundred bytes.

Compared to FAX, typical pages done in PostScript end up much more compact, transmit much faster, and offer "camera-ready" typeset quality. I cannot fathom why anyone would ever use FAX for anything.

I certainly do not.

Powerful new tools have recently been added to PostScript to make it an even better data compressor. They include Adobe's *Distillery* program and *Acrobat* document system plus my own triple distilling routines.

Much more on using these tools appears in the *PostScript Reference Manual II* "red book".

I guess those are most of the main methods for data compression today. We have looked at many of these in more depth in previous columns and the *Hardware Hacker* reprints.

The obvious next question is how can you go about…

Doing Data Compression

Any old PostScript level II printer has got built-in *filter* routines that let you quickly and cheaply encode or decode most compression schemes. Others are easily added. There's also

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NAMES AND NUMBERS

Adobe Systems
1585 Charleston Road
Mountain View, CA 94039
(800) 833-6687

Aware, Inc
One Memorial Drive
Cambridge, MA 02142
(617) 577-1700

Batelle Pacific Northwest
Box 999, K6-54-Watts
Richland, WA 99352
(509) 372-4274

CompuServe
5000 Arlington Center Blvd
Columbus, OH 43220
(800) 848-8199

Dialog Information Services
3460 Hillview Aveue
Palo Alto, CA 94304
(415) 858-2700

F-P Display Electronics
55 Green Street
Clinton, MA 01510
(508) 365-9150

GEnie
401 N Washington Street
Rockville, MD 20850
(800) 638-9636

Hewlett-Packard
PO Box 10301
Palo Alto, CA 94303
(415) 857-1501

Home Power
PO Box 130
Hornbrook, CA 96044
(916) 475-3179

Iterated Systems
5550A Peachtree Pkwy #650
Norcross, GA 30092
(404) 840-0310

Mahantango Manor
Hickory Corners Road
Dalmatia, PA 17017
(717) 758-8000

John Reese
Rt 1, Box 1551
Sautee, GA 30571
(706) 865-5495

Roberts Electric
311 N Morgan Street
Chicago, IL 60607
(312) 829-1365

Sharp
5700 NW Pacific Rim Blvd
Camas, WA 98607
(800) 642-0261

Stirling Machine World
1823 Hummingbird Court
West Richland, WA 99352
(509) 967-5032

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

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support tools to bop back and forth between strings and files.

You can even layer one filter up on top of another. As I've mentioned a time or three in the past, PostScript is an superb universal hacker's general purpose computing language.

Which is by far your simplest and fastest way to get started doing your own data compression work.

An example program for PostScript DCT (or JPEG) data compression is shown you in figure five. This takes a disk based binary format image and then DCT encodes it. After that, the data is made transparent by doing an ASCII-85 filtering.

The results are fairly impressive. What was a 49K binary file or a 98K Hex file becomes a 7K file that can be sent over a non-transparent channel. You can even stuff your final 7K file into a string to avoid a hard disk.

The differences in image quality are quite hard to spot and are "good enough" for pretty near any desktop

publishing use. Custom adjustments can be made for critical uses. Squash time is a few seconds.

We have a few suitable test images up on PSRT if you can't find your own. Along with examples on how to quickly and simply do your own data compression filtering. In particular, see files…

LENA.PS
HACK56.PS
HACK69.PS
STR2FILE.PS
LENAHIST.PS
IMAGEKIT.PS
MANDRILL.PS

Plus, of course, STARTUP.PS and SPEEDUP.PS.

Alternators as Steppers

In several past issues and in those *Hardware Hacker* reprints, we have seen how plain old car alternators can get converted into power steppers. A few files on this topic also do appear

on *GEnie* PSRT.

A new "down homey" video is now available that clearly shows you how to use car alternators as steppers. In a humongous automated sign routing machine. In its spare time, the same beast can create fancy and precision CAD/CAM parts for a weaving loom. Heddles and such. Doing everything totally homebrew at low cost.

The vid is $19.50 and is available from *John Reese*.

Magic Resources

If the technology used is advanced enough, it looks like magic. And I guess many Hardware Hackers see themselves as being magicians of one sort of another. Only we largely use new technology in place of the more traditional deception, distraction, and disorientation.

My favorite "magic" trick is to put a photocell beside a lightbulb in a positive feedback loop. You can then "light" your lamp with a match. And then blow the light out. On the first try, use a gentle puff. On the second, you puff harder. And, of course, on the third try, you'll cup your hands around the lamp (blocking the optical feedback path) and big-bad-wolf it.

For our totally different resource sidebar this month, I thought we just might list a few of those hard-to-find magazines and suppliers where real magicians go to buy their wands, top hats, rabbits, and whatever. There's a lot of oddball stuff here.

New Tech Lit

From *Hewlett-Packard*, a fat new *Optoelectronic Designers Catalog*. It has *LED* displays and optocouplers, along with bar code stuff, fiber optic comm, and robotic shaft encoders. From *Sharp*, a new bound collection of *Application Notes* on integrated circuits, liquid crystal displays, RF components, and optoelectronics.

More information on Stirling heat engines appears in *Stirling Machine World*, who also carry several books and software items on this topic.

Michael Hackleman's *Alternative Transportation News* has become a new feature section of *Home Power Magazine*. Plenty here on homebrew electric vehicles.

A good source of surplus hydraulic parts is *Roberts Electric*. Ultra large alphanumeric displays that use "flip disk" technology are available from *F-P Electronics*.

Classic phone parts and replicas are offered by *Mahantango Manor*. Even 1907 *Farmer's Line Sets* in real quarter sawn oak.

A pair of unique and free product development resources are offered by *Batelle Pacific Northwest*. One is the *Inventor Assistance Source Directory*. The other the *Prototype Development Assistance Providers* list.

But do not contact anyone on the second list unless either (a) your new product is already well into its third party advanced beta testing stage, or (b) you are willing to pay the industry standard development rates.

More on these topics also appears in *Midnight Engineering*.

Speaking of which, I've gathered all of my previous columns from ME together into my *Blatant Opportunist* reprints. Covers technical innovation, new resources, product development, self-publishing, and hackable new concepts.

The usual reminder here that I've gathered most of the stuff mentioned into two sidebars, *Magic Resources* for the magician items, and *Names and Numbers* for everything else.

Let's hear from you. ◆


```
% DCT compress a file and then ASCII85 encode it…

/sourcefilename (lena.histo.1) def                      % name source file
/targetfilename (lena.histo.dct.ascii85.1) def          % name target file

sourcefilename (r) file /source exch def                % open source file

targetfilename dup status {pop pop pop pop              % delete old target
deletefile}{pop} ifelse

targetfilename (w) file /target exch def                % open target file

5 dict  dup /DCTdict exch def begin                     % open work dictionary

save mark {                                             % start main loop

  /Rows 192 def                                         % height in pixels
  /Columns 256 def                                      % width in pixels
  /Colors 1 def                                         % one for b/w

  /buf Columns Colors mul string def                    % open work buffer

  target /ASCII85Encode filter /midtarget exch def      % define filters
  midtarget DCTdict /DCTEncode filter
  /filtertarget exch def

  Rows {filtertarget source buf readstring pop          % read-filter-write
  writestring} repeat

  filtertarget closefile                                % close files
  midtarget closefile
  target closefile

} stopped {handleerror} if cleartomark restore          % end main loop

end                                                     % close dictionary
```

Fig. 5 – THIS DCT COMPRESSED "LENA" IMAGE shows you how easy it is to do data compression in PostScript. Final transparent file size is 7K!

Don Lancaster's
Hardware Hacker

Digital photo imaging
Magnetic field resources
Fluxgate compass papers
A pair of new GPS books
Error diffusion techniques

November, 1993

Several readers have reported problems when logging on to my *GEnie* PSRT board. The trick is simple: Be certain to enter the HHH *immediately* after your comm software verifies a connection. You should then get prompted for an account number, and could proceed from there.

I have looked further at one of our "free energy" resources from a few columns back. *Rexearch* is one well done labor-of-love operation. What Rex has done is gather together his lifetime collection of weird science, junk science, pseudoscience, and utterly off-the-wall papers, patents, and press coverage. His typical $6 packages might include full copies of several patents and an article or two. There are hundreds of topics. All of them strange and wondrous.

This appears to be one of the finest personal collections of the technically weird anywhere. Stapled raw copies are used to keep costs down. A free master list is offered.

Yawn. Stupendous breakthroughs are a thankless task, but somebody has to do them…

Spotless halftones (!)

I've recently been exploring ways to improve digital photo quality. For laser, dot matrix, or inkjet printers. By going to a new *spotless halftone* technique that does non-obvious stuff in non-obvious ways, you can very much improve your print quality.

Stunningly so.

Ferinstance, most "experts" would agree that the "best" photo halftone you could do at a plain old 300 DPI resolution is something like 19 grays at 70 spots per inch or 15 grays at 85 spots per inch. Which, at its very best, will just barely miss ending up "sunday funnies" or "auto shopper" tabloid print quality.

Instead, figure one shows you a portion of a stock Lena digital photo, done using a brand new *spotless* 300 DPI halftone. This offers 65 grays, a grain that seems much finer than 106 spots per inch, and full compatibility with traditional ink.

I'd dearly love to show you the 600 DPI version, but we'd best not print it here since the **Electronics Now** press might gag on a 212 line screen. I will show you where to get your own copy shortly, though.

The bottom line: You can now print your own "useful" photos at 300 DPI and "very good" photos at 600 DPI. Photos for top quality Book-on-demand publishing. And often more than good enough to get rid of any need for high res typesetters.

To do so today does require some very careful attention to detail and an understanding of just what is coming down. But if you are willing to spend the time and effort needed to learn the basics, superb digital halftones can be yours. What I thought I'd do here is outline the secret insider tools needed for really great photos.

Traditional photography is often an extremely flexible and very forgiving process. If you don't like what you have, simply do some slopping in the slush to fix it. You can raise or lower brightness by opening up or closing down a stop. Change the contrast by printing one paper grade higher or lower. Or custom dodge out all your muddy grays and burn in your harsh highlights. Simple and easy.

Unfortunately, any digital halftone lacks this flexibility. Everything has to be exactly and precisely on the money. There is absolutely no room
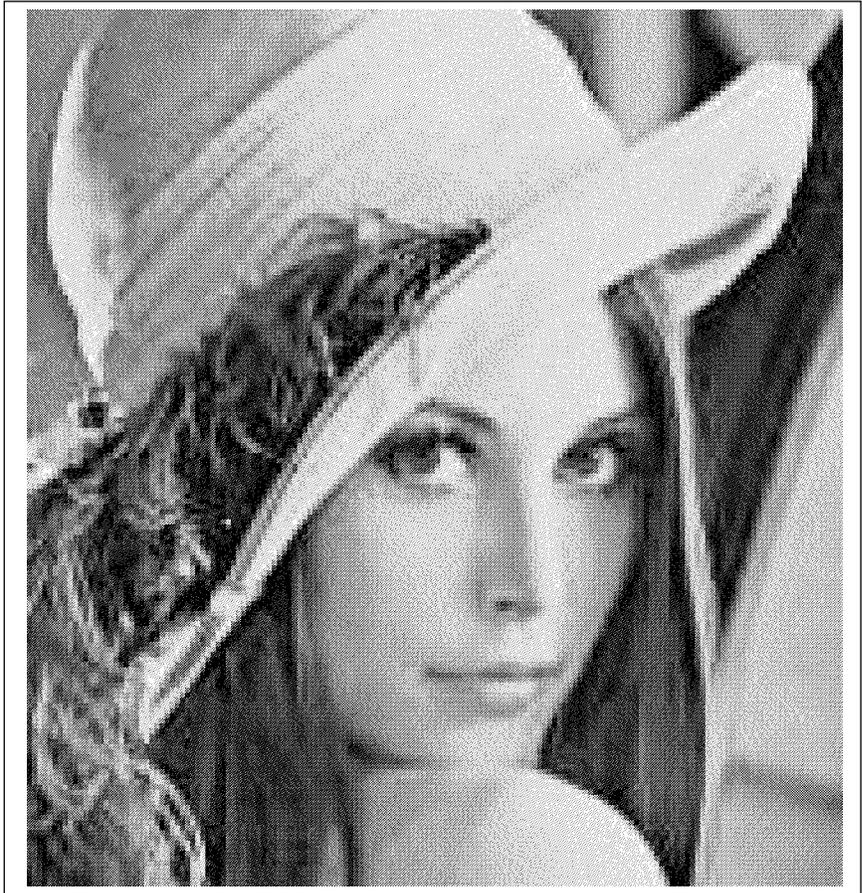
Fig. 1 – A SPOTLESS HALFTONE from an unenhanced 300 DPI laser printed original. With care, this new technique offers significantly better image quality than traditional methods. Results at 600 DPI are vastly superior.

Decent input data –

The original source material has to be first rate, including sampling of one pixel per pel to 64 or 256 gray levels.

Cropping –

Removes unneeded background info, focusing on the subject matter itself. Makes the subject relatively larger.

Histogram Equalization –

Makes each available gray work equally hard by redistributing the gray values in the image for best spread.

Gamma Correction –

Linearizes the display to eliminate dot gain and similar effects. Matches perceived to actual gray values.

Error Diffusion –

Eliminates or minimizes gray steps by spreading the step error out among several nearby pixels.

Spotless Haftones –

Combines the best features of dithering and halftones by using randomized multiple dots per cell.

Fig. 2 – TOOLS AND TECHNIQUES for superb digital halftones.

for forgiveness. Let's look at some of the essential tools we now have to improve digital halftones. We'll also summarize these in figure two…

Decent input data – "Garbage in, garbage out" is especially true for digital halftones. Unless you start off with your best possible image data, a disaster is a certainty. Each *pel*, or picture element in the original should correspond *precisely* to *one* pel in the final image. Those pel values must get *linearly* coded to at least 64 and preferably 256 gray levels.

Oversampling or undersampling can lead to all sorts of glitches. Not to mention unnecessarily long file sizes.

There's lots of tools available to do the job. Such as *Adobe Photoshop*. If you are careful, photo enhancement can instead be done by using the PostScript in your printer as a general purpose computing language.

Cropping – This is just throwing away outside areas that do not add to your image content. Always get the key theme or subject as obvious and as dominant as possible. But do keep your aspect ratio something sane, like 1:1 or 4:3 or 1.62:1. Others might end up visually jarring.

At any rate, the key point is to start off with the very best image you can. And then enhance it using every trick in the book.

Histogram equalization – Within limits, the more gray levels you can print, the better your results. If you only have a few grays available, you certainly do not want to ignore some of them. This can only make matters worse. Too few grays give you a step effect having annoying visible jumps between the gray levels.

Histo equalization can make each possible gray level equally important. To do an equalization, you plot the usage (or popularity) for every gray into a *histo plot*. Then you *reassign* your gray levels so that each one gets used equally often.

Histo is *absolutely essential* for all decent digital photos. Sadly, most image users have never even heard of histo. Or else refuse to spend the few seconds needed to do this incredible improvement. Lots more on this in HACK56.PS and in those *Hardware Hacker* and BOD reprints.

Gamma correction – Most printers and some display devices are very nonlinear. They might favor whites or

blacks. Or extremes over mid range. Every effort must be made to make a printer as linear as possible. Such things as engine technology, toner density settings and paper choices help a lot here.

The linearity plot is usually called a *gamma curve*. *After* you have done everything else you possibly can to improve your gamma, you may want to selectively "throw away" certain of your gray levels, so the remaining grays create the *illusion* of a more linear response. Thus you can trade off the total number of printing grays against the gamma for those grays.

Laser printers are notorious for a *dot gain* effect. A few details appear in figure three. The first goal in any laser printer is solid blacks. The black pixels on the page are square, but the laser spot is usually round. If you are going to completely cover a square hole with a round peg, the peg has to be larger. Each of these overlapping segment quadrants creates a net dot gain of 14 percent or more.

The net effect on any "black write" laser printer is to make surrounded black pixels 1.56 times *larger* in area than desired, and any surrounded white pixels 0.44 times *smaller* than usual. And possibly worse. What this does is very strongly favor all your blacks and deep grays. Ferinstance, a 50 percent gray that alternates white and black pixels can end up way on down at a mere 22 percent gray. And the "white write" systems will do the exact opposite.

Proper gamma correction is super important. So is picking halftoning that avoids alternating pixels.

Error diffusion – The big problem with a limited number of grays is that you'll get steps on any gray crossing, rather than a smooth gradient. At the crossing, you have an error. An error whose difference is the gray you want minus the gray you got.

A new technique known as *error diffusion* takes the error you had and then dribbles it out among several future pixels. On even lines, you zero out your current error and then add some of your error to the next pixel to the right, some to the next below and left, some to the next below, and the rest to next below and right. On odd lines, you lean to the left rather than

to the right.

Your net result is that any sharp jumps can get replaced with diffused blends. Instead of steps, you get a fairly smooth gradient. Diffusion is best used at higher resolutions.

If the steps end up very exact and repeat over and over again vertically, you may get repeating artifacts. This can happen if the error diffusion math keeps coming up with an identical number sequence. To beat this, you simply *add* some noise to your data so the numbers do not repeat. On a 256 level gray subject, you might randomly replace 15 percent of your gray 56 values with a substitute value of 53, 54, 55, 56 or 57.

This is an example of *adding* noise to make something look better! The trick here is that your added noise is random and high in frequency. Thus it can be almost invisible. Purposely adding noise can eliminate any low frequency artifacts.

Properly done error diffusion can make 600 DPI artwork look like it was done on a premium phototypesetter of much higher resolution.

Error diffusion is also very useful for blends and waterfalls inside of larger typography. Any steps are especially annoying here.

Error diffusion utilities appear on *GEnie* PSRT.

Spotless halftones – Any time you do anything digitally, you'll end up with approximations. The sampling process inherently adds noise, giving you both your intended signal and some *artifacts* of one kind or another. Typically, these artifacts may appear as grainy dots. Or as distinct gray steps. Or as visual "bulldozer track" or "droput" artifacts.

O.K. We *must* have noise in any digital system. And we might even want to purposely *add* more noise. As we've just seen, carefully added noise in a digital system can often *raise* your final perceived signal to noise ratio! CD audio does it all the time. Now the trick here is simple: *Make the unavoidable noise work for you, rather than fight you.*

Certain types of noise look much worse than others. Large repeating spots are bad. Quantized gray levels are bad. Anything that happens over and over again in a row or a column

(A) Geometry of a round spot covering a square pixel.

0.14 north overlap
0.14 west overlap
required coverage of 1.0 unit pixel
0.14 east overlap
0.14 south overlap

(B) A "white write" printer will favor the lighter grays.

This is intended to end up a 50% gray

(C) A "black write" printer will favor the darker grays.

This is intended to end up a 50% gray
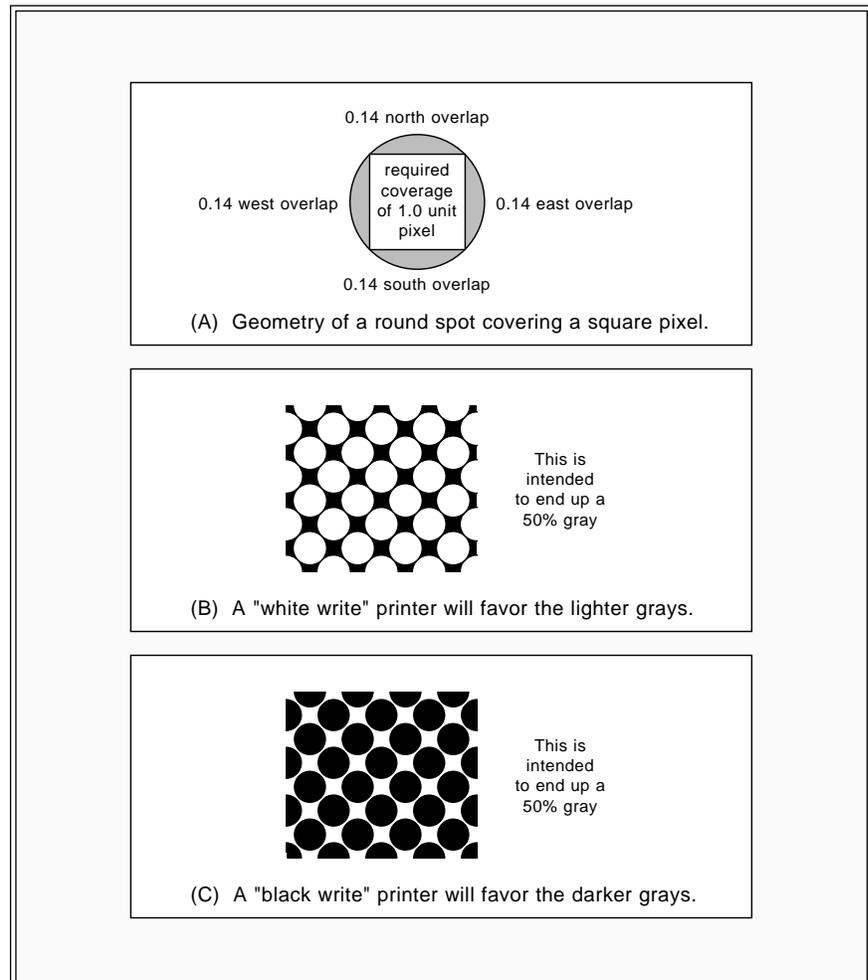
Fig. 3 – LASER PRINTER DOT GAIN occurs whenever a round spot tries to cover a square pixel area. Dot gain creates a nonlinear gamma curve.

is bad. Thus, we have "good noise" and "bad noise".

To optimize things, make your "good" noise…

- as random as possible
- as uniform as possible
- as consistent as possible
- as far spread out as possible
- as high a frequency as possible
- as visually diagonal as possible

Let's assume you have a square 8 x 8 cell of dots that you can only turn completely on or off. Which should give 65 gray levels, including black and white. There are two traditional methods of converting this cell into a "gray" splotch on your page, called *halftoning* and *dithering*.

With halftoning, you'll create *one* black area in the middle of your cell and let it "grow" as you go blacker.

Just the same as a traditional printer's halftone dot. Your quantizing noise will obviously be low frequency and will repeat regularly.

The low frequencies and obvious repetitions are just about the *worst* possible types of noise you can have in your halftone.

In theory, a dithering can greatly improve on your noise artifacts. With dithering, you create a pattern of the correct number of dots spread out as uniformly as you can inside your cell. You'll end up with a very high noise frequency and a more or less uniform noise distribution. So, dithering can *theoretically* give us lower noise and pleasing results.

Unfortunately, dithering has a few nasty habits. If you've got dot gain, then the dithered patterns can end up *much* darker than you intended. The

Low cost dead reckoning sensors –

Alan Phillips, *Institute of Navigation 1993 Tech Meeting Proceedings*, Alexandria, VA, USA, p 145-150, 1993.

Three-axes fluxgate magnetometer with multiplexed sensors –

A. de Sa and K. Heron, *Measurement Science & Technology*, v 4 n 5, May 1993, p 633-634, ISSN: 0957-0233.

Ring core fluxgate sensor null feed-through signal –

J. Peterson, et al, *Measurement Science & Technology*, v 3 n 12, Dec 1992, p 1149-1154, ISSN: 0957-0233.

Review of fluxgate sensors –

Pavel Ripka, *Sensors and Actuators*, v 33 n 3, Jun 1992, p 129-141, ISSN: 0924-4247.

Bipolar magnetometer sensor similar to fluxgate device –

R. Dalpadado, *Electronics Letters*, v 28 n 17, Aug 13 1992, p 1662-1663, ISSN: 0013-5194.

Micromachined solenoids for highly sensitive magnetic sensors –

S. Kawahito, *IEEE '91: 91 Int Conf Solid State Sens Actuators*, p 1077-1080, ISBN: 0-87942-585-7.

Simple fluxgate magnetometer using amorphous alloys –

S. Ghatak, *Journal of Magnetism and Magnetic Materials*, v 103 n 1-2, Jan 1992, p 81-85, ISSN: 0304-8853.

Analysis of a fluxgate magnetometer based on metallic glass –

O. Nielsen, *Measurement Science & Technology*, v 2 n 5, May 1991, p 435-440, ISSN: 0957-0233.

Improved fluxgate for compasses and position sensors –

Pavel Ripka, *Journal of Magnetism and Magnetic Materials*, v 83 n 1-3, Jan 1990, p 543-544, ISSN: 0304-8853.

Fig. 4 – SOME NEW REFERENCES for fluxgate compasses.

midrange gray level #32 could end up down below deep gray #22 if you are not extra careful. You might end up with a very bad gamma curve.

Note that that brand new "FM" or *Crystalprint* technology is simply a variation on plain old dithering. And just like dithering, the dot gain can be excessively high for toner based laser printer apps.

Dithering can have annoying and quite obviously repeating artifacts, especially in large gray areas. These can look just plain awful. Finally, dithering creates spots that are tiny by traditional printshop standards. A fully dithered halftone often can *not* be reproduced in ink!

The secret scoop

What you do for spotless halftones is take the best features of halftoning, error diffusion, and a good gamma correction. Then combine them in an optimum way that best obeys all our "good noise" rules above.

Let's start with all those repeating artifacts common to dithering. To get rid of these, you simply select one of *n* possible dither patterns for a given gray. You do this at random. A good choice for *n* is usually eight. You do want to make sure all of your selected patterns have their dots as far apart from each other as possible and that each row and each column gets hit *exactly* the same number of times for the entire pattern set.

Next, instead of using the "single dot" of a halftone or those "too many dots" of dithering, you pick only a *few* dots per cell. Use enough dots to raise your grain frequency but not enough to cause excessive dot gain. Eight dots per cell could be a useful compromise. You allow each of these eight dots grow in the same manner as you would one halftone dot. You randomize "which dot grows how" to minimize long term repeats.

Finally, you throw away a few of your available grays to do a gamma correction and balance the brightness. But note that your grays have to be

thrown away *before* you do your histo equalization! Otherwise, some of the grays will be more heavily used than others.

Spotless halftones can be based on image masks, on patterns, or even done as characters in a custom font. I'm still working on several of these exciting new variations.

One possible 600 DPI result is a picture having the same *information content* as a 75 spot per inch halftone, 64 uncorrected gray levels, and grain equal to 212 spots per inch. Except that randomizing can make the grain even *less* obvious. Any 256 x 256 pel image can end up around 3.4 inches square at 600 DPI and a giant 6.8 inches square at 300 DPI.

There are lots of options in this emerging new technology.

For more information

Naturally, that PostScript general purpose hacker's computer language is absolutely ideal for exploring high quality digital photos. I've posted lots more on the spotless halftones to my *GEnie* PSRT. Especially in our files SPOTLESS.PS and RETOUCH.PS. We also have great heaping bunches of files on related imaging topics.

SPOTLESS.PS will give you that 600 DPI Lena I promised earlier.

Low level magnetic fields

There has been a lot of helpline interest in measuring weak magnetic fields lately. Perhaps you need an accurate solid state digital compass. Or want to do some archaeologic site mapping. Or lava tube cave hunting. Or are concerned about field safety. Or are trying to date an ancient pot, fireplace, or geological formation. By applying either *archaeomagnetism* or *paleomagnetism* tools.

Magnetic field intensity is a *vector* quantity that needs both an intensity and a direction. If you take a coil and run a current through it, you will get an intensity of one *Gauss* if you use 2.02 ampere turns per inch.

The earth's magnetic field is even weaker. Ferinstance, here in Arizona, the field is 0.26 Gauss or so. It has a 59 degree *inclination* and a 14 degree *declination*.

For openers on all this, there's an *Earth's Field Magnetometry* classic paper by W. F. Stuart in *Reports on*

Progress in Physics, 1972, vol 35, p. 803-881. Essential reading.

A smaller magnetic measure is a *gamma*. There are 100,000 gammas in a gauss. A one gamma sensitivity or better is desirable for archaeological mapping. A ten gamma sensivitity is needed for a decent compass.

At first glance, there seem to be five schemes for measuring any weak mag fields. These are the *compass*, those *Hall effect* devices, the *proton precession magnetometer*, the *magnetoresistor* and the *fluxgate*. But the fluxgate is ridiculously better than the others and is the *only* one you should really consider.

A compass is basically a magnet on a string. It twists around and points north. Problems include mechanical motions, very low sensitivity, and the ability to only measure the direction of the field.

The *Hall effect* is the transverse current produced in certain materials in the presence of a magnetic field. Lower cost sources for Hall devices include *Allegro*, *Texas Instruments*, and *Micro Switch*. These are great for working with real magnets. But Hall effect devices lack the required low field sensitivity by a factor of 1000 or more. And are thus *totally useless* for weak field measurement.

Er, with two minor exceptions. The *Dinsmore* people have combined a traditional compass with hall sensors for a low cost device with a 45 degree resolution. Or 22.5 degree res if you stack a pair of them. And the *F. W. Bell* folks now supply a huge and rather expensive Hall effect sensor assembly that theoretically could be used for a low res compass.

A proton precession magnetometer is just a bottle of distilled water with a coil around it. A strong current is routed through the coil and then gets suddenly released. The mag field shift can cause a wobble in certain hydrogen atoms. A process known as *Larmor precession*. The frequency of this precession is proportional only to the magnetic field strength. But not to its direction. Typically, the frequency is in the 1300 Hertz range and only lasts for a few hundred cycles. At a few microvolts maximum. Accurate measurement here is not trivial.

An important proton magnetometer paper showed up in the August 1956

WEAK MAGNETIC FIELD RESOURCES

Autohelm
Anchorage Park Eastroad
Portsmouth Hants P03 5TD
ENGLAND

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

Dialog
3460 Hillview Avenue
Palo Alto, CA 94304
(415) 858-2700

Dinsmore Instrument
1814 Remell Street
Flint, MI 48503
(313) 744-1330

GPS World
859 Willamette Street
Eugene, OR 97401
(503) 343-1200

Institute of Navigation
1800 Diagonal Rd, Ste 480
Alexandria, VA 22314
(703) 683-7101

KVH Instruments
110 Enterprise Center
Middletown, RI 02842
(401) 847-3327

Magnetics, Inc
Box 391
Butler, PA 16003
(412) 282-8282

Micro Switch
11 W Spring Street
Freeport, IL 61032
(815) 235-6600

Murata
2200 Lake Park Drive
Smyrna, GA 30080
(404) 436-1300

NASA
Langley Research Center
Hampton, VA 23665
(804) 865-3281

NASA Tech Briefs
41 E 42nd Street Ste 921
New York, NY 10017
(212) 490-3999

Phillips
PO Box 3409
Sunnyvale, CA 94088
(800) 447-1500

Speleonics
Box 5283
Bloomington, IN 47407
(812) 339-7305

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

TDK
1600 Feehanville Drive
Mount Prospect, IL 60056
(708) 803-6100

Texas Instruments
PO Box 809066
Dallas, TX 75380
(800) 336-5236

Walker Scientific
Rockdale Street
Worcester, MA 01606
(800) 962-4638

Review of Scientific Instruments. You might also find *IEEE Transactions on Geoscience Electronics*, GE-9 #2, for April 1971, pages 99-103 of value. As well as the *Introduction to Magnetic Resonance* by A. J. Carrington; and *Nuclear Magnetic Relaxation* by W. Benjaman.

A proton precession magnetometer simply is not worth the hassle these days. Why? Because the upcoming fluxgate is both ridiculously simpler and offers better sensitivity.

The *magnetoresistor* is an orphan technology still kicking around for no apparent reason. This is a device whose resistance will change when a magnetic field gets applied. Sources include *TDK*, *Murata*, and *Philips*. But their sensitivity is apallingly low and they have nasty habits of needing exotic external magnetic biasing and suddenly flipping without warning.

Avoid this turkey.

The *fluxgate* is by far the best of the batch. Which is a saturable toroid coil with two or three windings. It is simple, cheap, and offers outstanding sensitivity. Very hacker friendly to boot. A *control* winding will wrap around the core. This will alternately saturate and unsaturate the core. The *sense* winding goes *across* the core. A second sense winding can be added at right angles to the first for *sine* and *cosine* channels.

In operation, the core permeability gathers in the earth's field when it is unsaturated and does nothing when saturated. The gathering in and the release of the field induces pulses in the sense windings. These pulses are proportional to the strength and the direction of the sensed mag field.

Sadly, I know of no cheap source for a hacker fluxgate sensor. *Radio*

Shack has apparently dropped their fluxgate car compass. Pricey units are avialable off the shelf from KVH and *Autohelm*. You can make up your own fluxgate sensor by starting off with a *Magnetics* 50086-2F core and using a control winding of 143 turns of #30 wire plus a pair of sine and cosine sense windings of 1000 turns of #35 wire. Additional details appear in the *Hardware Hacker II* reprints.

Other sources for fluxgate details include *NASA Tech Brief* LAR13560; a pair of articles in the Dec 81 and Jan 82 issues of *Sport Aviation*; IEEE transactions MAG-8 #1, pages 76-82; and various coverage in *GPS World*, in that *Journal of Navigation*, and in *Speleonics* magazine.

If you do know of a good hacker fluxgate source or want to sell these yourself, be sure to let me know. An *Incredible Secret Money Machine II* for your trouble.

My story on archaeomagnetism and paleomagnetism appeared in the September 1969 issue of *Electronics World*. Way back when.

Lower level magnetic field sensors and instruments are available through *F. W. Bell* and *Walker Scientific*.

As with any technical subject, you can instantly get up to date anywhere in the world at any time of day by using the *Dialog Information Service*. As we found out last month, Dialog is newly available on a cash-and-carry basis by way of either *CompuServe* or *GEnie*. About thirty cents per title.

A quick Dialog dump disclosed the recent fluxgate papers of figure four.

I've tried to gather many of these references into this month's resource sidebar.

By the way, if you've ever got any ancient "horses mouth" references in any field, all you have to do is use the *Science Citations Index* to pick up any later developments. Unlike most resources this magic reference lets you work *forward* in time, picking up newer and newer material.

New Tech Lit

From *Motorola*, a *Semiconductor Master Selection Guide*. Plus a new two inch thick *Linear Circuits Data Book* from *Texas Instruments*. About 1500 pages worth. A definitive tome fer sure. From *Hitachi*, the *Wireless Communication IC Summary*.

Metermaster is an old-line supplier that offers a wide variety of name brand test gear from all of the major suppliers. A free 752 page catalog.

There is now a brand new method of using PC parallel ports that is both very high in speed and bidirectional. This major comm improvement is the *Boise* IEEE.P1284 spec. More details on the spec from the *IEEE*, while info on Windows software drivers can be found through *HP Peripherals*.

The *Trimble Navigation* folks have long offered a great no-charge intro book titled *GPS: A Guide to the Next Utility*. They have just added a new *Differential GPS Explained* title.

Differential GPS offers sub meter nav and position accuracy. Even if your military purposely fouls up the satellite signals. The secret is to have a second nearby receiver in a fixed and known location.

Finding printed circuit resist ink for plotting pens can be a real hassle. One costly supplier is *Fast Proto*. A free ISMM if you can come up with a less outlandishly overpriced source.

ATV Today is a new newsletter for Amateur Television industry insiders.

Our two obscure trade journals for this month are *Access Control*, all about mag stripe readers and such. Or *Information Display* for lots on LCD, LED, and CRT display technologies.

A reminder that a really great new $19.50 video on rewinding your own auto alternators for use as CAD/CAM power steppers is obtainable through *John Rees*.

For all the fundamentals of digital integrated circuits, do check into my *TTL Cookbook* or *CMOS Cookbook*. Either by themselves or as a portion of my improved *Lancaster Classics Library*. See my nearby *Synergetics* ad for more info. Or send for a free brochure.

As usual, I've gathered most of the items mentioned into the *Names and Numbers* and the *Magnetic Resources* sidebars. Always check here first. ❖

Digital Bogey contest
Multimedia resources
CTCSS tone squelching
Coin mechanism sources
Low distortion sinewaves

New hacking opportunities do seem to be emerging daily. Word has it that there are bunches of new aps coming down over those video camera CRT viewers and their support chips. Such as tiny oscilloscopes, VGA interfaces, virtual reality lashups, 3D stereo, and even precision graticules.

Another exciting new area is called *binary optics*. This one is a sure fire school paper or college thesis winner. In binary optics, zillions of plain old opaque dots are carefully placed on a flat sheet. Binary optics can replace exotic combinations of costly lenses.

Amazingly, at least one researcher is using nothing but PostScript and a grunt phototypesetter for his optical designs. Cheaper CD-ROM optics will be an important early use.

More on these two as they unfold. Meanwhile, let us look at an obscure standard that has lots of nonobvious new hacker uses…

Tone signaling

I do get lots of helpline requests for schemes to let you route voice and data over the same audio channel at the same time. Interference free, of course. You might want to do this to control a multimedia slide show. Or for selective calling on a multi-party intercom. Or for remote robotics.

Or as a handicapped aide. Or home automation. Or as a monitor for an alarm system. Or as some animation script to get saved to a cassette tape. Or as an "I've got the answer!" game or quiz response. Or to synchronize effects on a carnival ride. Or for use as a radio private calling feature.

Since any particular comm channel has a well-defined bandwidth, there are definite limits as to what you can and cannot do here. So, we'll assume that low data rates are usable.

Touch tones could get used, but all of those beeps and blorps might end up annoying. The touchtone chips are offered by *Teltone*, *Silicon Systems*, or *Radio Shack*.

But those *MX-Com* folks appear to have a much better way. There is an obscure mobile comm scheme called CTCSS, and short for the *Continuous Tone Controlled Sub-audible Squelch*. The related standard is EIA-220-B.

As figure one shows us, there are 39 standard or nearly-standard tones in the spec, ranging from 67 Hertz up to 250.3 Hertz. In their intended use, these tones are combined with voice messages on any radio channel. Only those channels set up to decode their selected tone can hear their message.

Tone Frequency	D5 (pin 5)	D4 (pin 6)	D3 (pin 7)	D2 (pin 8)	D1 (pin 9)	D0 (pin 10)
67.0	1	1	1	1	1	1
69.3	1	1	1	0	0	1
71.9	0	1	1	1	1	1
74.4	1	1	1	1	1	0
77.0	0	0	1	1	1	1
79.7	1	1	1	1	0	1
82.5	0	1	1	1	1	0
85.4	1	1	1	1	0	0
88.5	0	0	1	1	1	0
91.5	1	1	1	0	1	1
94.8	0	1	1	1	0	1
97.4	1	1	1	0	1	0
100.0	0	0	1	1	0	1
103.5	0	1	1	1	0	0
107.2	0	0	1	1	0	0
110.9	0	1	1	0	1	1
114.8	0	0	1	0	1	1
118.8	0	1	1	0	1	0
123.0	0	0	1	0	1	0
127.3	0	1	1	0	0	1
131.8	0	0	1	0	0	1
136.5	0	1	1	0	0	0
141.3	0	0	1	0	0	0
146.2	0	1	0	1	1	1
151.4	0	0	0	1	1	1
156.7	0	1	0	1	1	0
162.2	0	0	0	1	1	0
167.9	0	1	0	1	0	1
173.8	0	0	0	1	0	1
179.9	0	1	0	1	0	0
186.2	0	0	0	1	0	0
192.8	0	1	0	0	1	1
203.5	0	0	0	0	1	1
210.7	0	1	0	0	1	0
218.1	0	0	0	0	1	0
225.7	0	1	0	0	0	1
233.6	0	0	0	0	0	1
241.8	0	1	0	0	0	0
250.3	0	0	0	0	0	0
no tone	1	1	0	0	0	0
serial input	1	0	data	clock	x	x
test mode	1	1	0	0	1	1

Fig. 1 – THE EIA-200-B CTCSS (Continuous Tone Controlled Subaudible Squelch) tones can solve many hacker problems that require simultaneous voice and data signaling over the same channel. These may be hardwire or serial programmed using the MX365A codes shown.
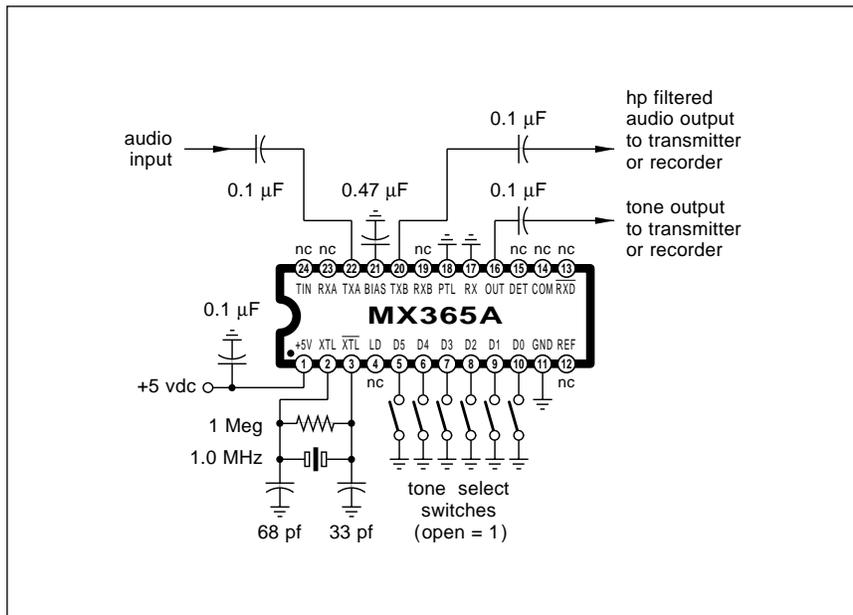
Fig. 2 – TONE ENCODER using the MX365A.

The tone frequencies are *subaural* in that most phone or mobile comm gear sharply attenuates audio below 300 Hertz or so.

The MX365A is a typical chip that can be be used either as the encoder of Figure 2 or the decoder of Figure 3. This circuit offers your choice of hardwire programmable tones or a serial computer control. I've shown

the hardwire mode, using the coding of figure one.

The MX365A costs $8 in singles.

If you directly apply low frequency signaling tones, any lower speech or music frequencies could interfere on transmit. This bad scene is known as *talk-off*. And you will hear the actual tones on receive.

To beat these problems, a special

digital high pass filter is included on chip. In the transmit mode, the filter gets rid of any low frequency audio that could interfere with your tones. You run your input audio through the filter and then combine the tones with the filtered output.

Note that the encoder chip does *not* combine the tone output with the high pass filtered input audio. You have to externally add these two together.

Use an op amp or a pair of summing resistors, or whatever. This external adjustment should give you the most flexibility to adjust levels.

If any compression or an automatic level control gets used, it goes *before* the tone encoder, not after it.

The presence of tones causes your decode output pin 13 to go low. For normal use, a low pin 13 also turns *on* the output audio. Pin 18 is a *push to listen* feature. Hold this pin at the positive supply to provide continuous tone-independent audio.

There is also one really cute hack included in the encoder that can get rid of any *squelch tails* during normal comm. See the data sheet for details.

You'll need several receiver chips if you need several tones.

The tone frequencies are set by the 1.000 Mhz crystal. Presumably, you could lower your input clock to lower all the available tones. Or to hit some "magic" frequency. This would end up as nonstandard, of course. But it would let you up your audio quality by way of an improved low frequency response. And might make your tones even more invisible.

Your maximum data rates would also have to get sharply reduced for lower tone frequencies. Better figure around 30 tone cycles as a minimum signaling interval. At 30 Hertz, this would mean about one command per second maximum.

You want a baud rate, you got it. One baud!

Use the lower tone frequencies for minimum audio interference. Use the higher ones for faster signaling.

MX-Com offers several variations on their basic chips. The MX315A is transmit only. Their MX265A has a better microprocessor serial interface. Their MX165B runs on a lower supply of 3.6 volts. A tone squelching and a speech scrambling get combined in their MX375 or the MX275.
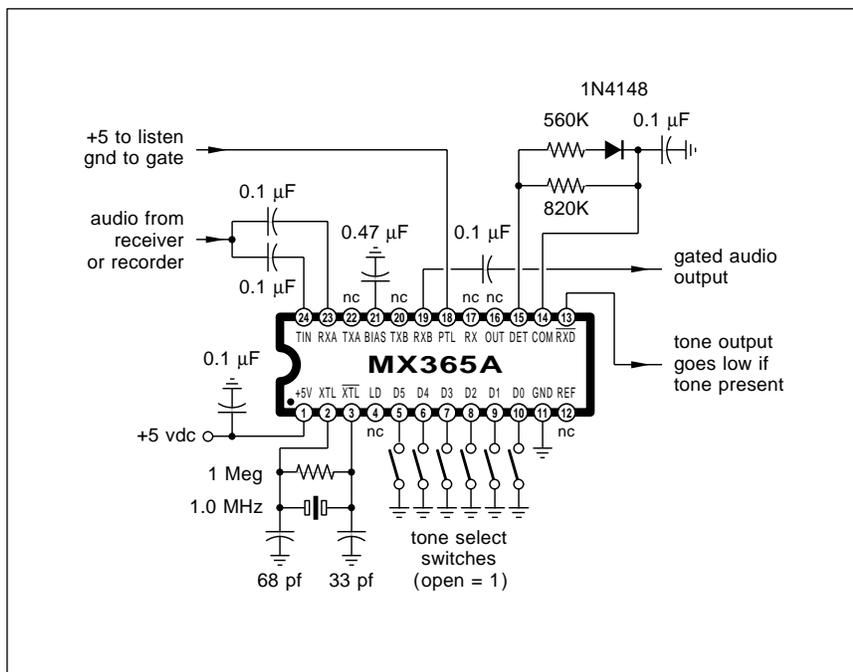
Fig. 3 – TONE DECODER using the MX365A.

Multimedia Resources

What is multimedia? The term can mean just about anything to anybody. I'll call this one *the use of computers for control of high quality video and audio*. Personally, at low cost, and on your own desktop.

Two hot multimedia buzzwords are *convergence*, which tells us that tv sets, cable services, and telephones are getting more like personal computers and vice versa. And *nonlinear editing*, which means that you'll no longer have to edit materials in their traditional "A-B roll" order.

Newer Macs or that Amiga based *NewTek Video Toaster* do seem to be running away with all the multimedia marbles these days. NewTek recently introduced the *Screamer*, a small and cheap box that does the work of *forty* networked Video Toasters.

Besides completely blowing away supercomputers and workstations at their end game, this one ridiculously shortens the rendering time needed for full animation sequences.

As our resource sidebar for this month, I have gathered together a few of those magazines and other sources that I have found personally useful to keep up on multimedia happenings. The list is not complete, so please let me know more about your favorite multimedia resources.

One thing that multimedia should eventually lead us to is…

The Digital Bogey

The Screamer is only backing up for a good start. Within a very few years, computers *will* be smarter than people. The time this will happen is arguable, but it definitely will occur somewhere between 2:24 and 2:26 AM on April 17, 1998.

Pacific standard time.

Note that one gig RAM is rapidly approaching first silicon. As is 1000:1 fractal and wavelet compression.

At that point, we will routinely be handling both gigabytes of RAM and terabytes of efficiently compressed and realtime HDTV accessed offline storage. All at low cost.

Sometime after that, all portions of a multimedia experience could get handled fully digitally. *Everything* in a movie will consist of flexible and easily manipulated data bases.
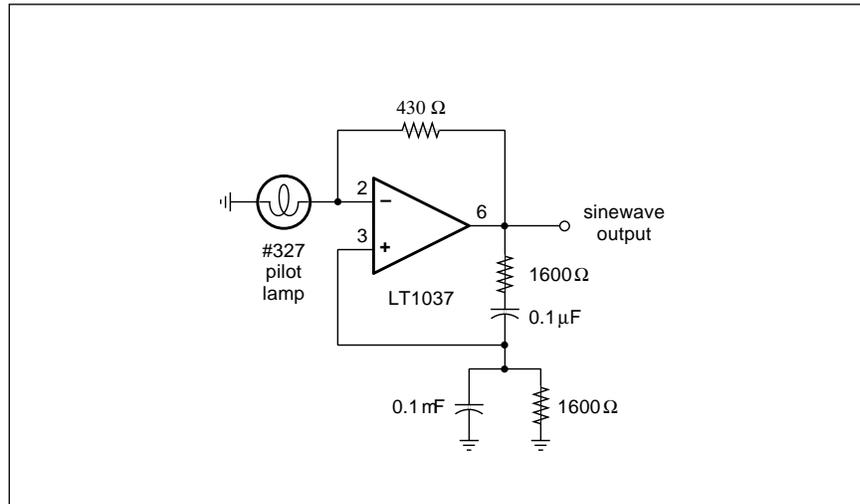
Fig. 4 – AN ULTRA LOW DISTORTION 1 kHZ SINEWAVE GENERATOR. The pilot light acts as a stabilizing AGC loop in this elegantly simple circuit.

There will be no difference at all between actors and props!

Everything will be a special effect. Live actors will, of course, be totally unnecessary. As will the gaffers and grips and Foleys. Or, for that matter, third assistant makeup advisor safety consultant best boys.

Given these stunning increases in desktop computing power, within two or three decades at most, it should be possible for one individual at home to produce something comparable to a first run movie. At a total cost of, say, $75. Compared to the $75,000,000 or so for today's old-line flicks. *Which should give us a one million to one reduction in the costs for producing movie-like experiences.*

The primary video distribution, of course, would be by way of *Internet IV*. With later releases through those library Teracubes, each of which can hold a decade or so of movies.

Naturally, the original script writer receives the lion's share of all income generated. And the final product will be *exactly* what the script writer had in mind.

I'll call this inevitable happening the *Digital Bogey*. As in Humphrey. A digital database should be able to totally define an actor's personna on a pixel-by-pixel basis. Both at macro and micro levels. Just like we process words and desktop publish today.

After teaching the data base all of the existing Bogey flicks, we simply switch to auto and let 'er rip. Presto.

Zillions of brand new Bogey movies.

For our contest this month, tell me more about the new upcoming Digital Bogey. Show me in 175,000 words or less what the consequences will be for a 1,000,000:1 reduction in all the costs of producing and distributing an entertainment experience comparable to a first run movie.

Among other things, we can expect a shift in smog levels in the LA basin. *All* types of LA smog.

As usual, there'll be a dozen or so of my new *Incredible Secret Money Machine II* books going to the better entries, with an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two that will go to the best of all.

Elegant simplicity again

Elegant simplicity is a theme that we do keep returning to over and over again here, as it should be one of your foremost hardware hacking goals.

Just as the P-38 can opener is by far the finest invention of the twentieth century bar none, there are electronic circuits which clearly do more with less. Using the bare minimum of parts to provide unexpectedly sophisticated final results.

We've run many elegantly simple circuits on these pages, but there is one clear cut winner which remains head and shoulders above all of the others put together. This, of course, is that original *Hewlett Packard* audio sinewave generator.

The *Linear Technology* folks have

long had a LT1037 ultra low noise op amp they are still real proud of. The gain of 20 million, offset of 25 *micro* volts and common mode rejection of 117 decibels are all right up there in the "adequate" range.

Beyond "fair to middlin".

So, they naturally used the all-time finest circuit anywhere ever in their technical lit. This one gets shown in figure four. It is an ultra-pure 1 kHz sine wave generator. How pure? Less than 0.0025% distortion and 0.001% percent noise for a 6 volt RMS output.

The circuit is called a *Wein Bridge* oscillator. Temporarily assume that the light bulb acts like an ordinary resistor, providing a fixed gain of +3 for the opamp. Now, at precisely 1 kHz, the series RC network will have *twice* the impedance of the shunt RC network, and both will offer the exact same phase shift. So, you'll have a sinewave running around an op amp having a gain of 3 and a network that has a loss of 1/3.

The feedback network can act as a single pole highpass filter while that shunt network acts as a single pole lowpass filter. Should the frequency change, the shifting impedance levels will automatically return it to where it belongs.

Leaving the *status quo* right where it's at.

Now for the most elegant part. The circuit only works when that op amp *already* has a sinewave present and a gain of precisely 3.0. If your gain is even a tad less than this value, the amplitude dies off. Slightly more, and your amplitude keeps getting bigger until it distorts badly.

Obviously, for this circuit to work we need some way of regulating the gain of the op amp. Set it above 3 to get it started, and then continuously adjust things to stabilize your desired amplitude. Naturally, you could do this using an AGC or *automatic gain control* loop.

Maybe an amplifier, a detector, and some sort of fancy multiplier stage. Any aerospace engineer could come up with a 10 chip $500 solution. If he is given a few technicians and enough simulation time on a mainframe.

Would you believe you can use a plain old light bulb instead?

An incandescent light bulb is an example of a *nonlinear* resistance. If there is very little voltage across it, the resistance of the cold bulb stays fairly low. When the voltage across the bulb (and the current through it) increases, the bulb warms up and the resistance increases.

The light bulb is a fully automatic, one piece AGC circuit! On power up, it is a low resistance, and gives you enough gain to start oscillating. At run time, its resistance continuously adjusts itself to give you a constant and low distortion output.

The thermal inertia of your lamp guarantees that all the AGC variations should stay long term only, instead of distorting the output waveform.

Which gives you elegant simplicity

at its very finest.

Both RC networks must be very carefully matched. Preferably better than one percent. That 327 is a stock pilot light usually rated at 28 volts and 40 milliamperes.

As a second contest this month, tell me about your favorite example of elegant simplicity. Concepts similar to this superb sinewave oscillator, a P38 can opener, or a vortex cooler.

Let's hear from you.

Coin changers

I have recently gotten bunches of requests for low cost sources of video game coin mechanisms. As surplus, these are largely catch-as-catch can. But *Marlin Jones*, *American Science & Surplus*, and *Herbach & Rademan*, sometimes stock these.

For larger quantities, try the ads in *RePlay*, *Playmeter* or the *Automatic Merchandiser*. For antique versions, try the *Player Piano Company* or the ads in *Always Jukin'* magazine.

Lutech and *American Changer* are two sources for the dollar bill changer mechanisms.

If you come up with other sources here, please let me know.

New tech lit

The Electrochemical Society is a good source for info on new battery technology, fuel cells, electroplating, corrosion, conductive polymers, and even Buckeyballs. They publish their *Interface* magazine and hold lots of trade conferences.

The third edition of the *Almanac of UFO Organizations and Publications* is offered by *Phaedra*. Authored by David Blevins and priced at $19.50. This is a combined Thomas Registry and Michlein Guide to the field. Of the 400+ resources listed, at least one of them (AI-TRAD) puts their money where their mouth is – one million dollars cash to anyone who is able to provide some *solid* evidence of either UFO's or aliens.

A fine selection of books and other handicapped resources is found at the *Disability Bookshop*.

Free samples of socket head caps are available from *Shear-Loc*. These instantly convert plain old cap screws into knurled knobs or thumbscrews, rosette grips, or tee-handles. Only a bench vise is needed for assembly.

NAMES AND NUMBERS

Always Jukin'
221 Yesler Way
Seattle, WA 98104
(206) 233-9460

American Changer
10273 NW 53rd Street
Ft Lauderdale, FL 33351
(800) 741-9840

American Science & Surplus
601 Linden Place
Evanston, IL 60202
(708) 475-8440

Automatic Merchandiser
PO Box 803
Fort Atkinson, WI 53538
(414) 563-6388

Disability Bookshop
PO Box 129
Vancouver, WA 98666
(800) 637-2256

Electrochemical Society
10 South Main Street
Pennington, NJ 08534
(609) 737-1902

Gas Engine Magazine
PO Box 328
Lancaster, PA 17603
(717) 392-0733

Global Engineering Documents
3130 S Harbor Blvd Suite 330
Santa Ana, CA 92704
(800) 854-7179

Herbach & Rademan
18 Canal Street
Bristol, PA 19007
(215) 788-5583

Iron-Men Album
PO Box 328
Lancaster, PA 17603
(717) 392-0733

Marlin Jones
Box 12685
Lake Park, FL 33403
(407) 848-8236

Linear Technology
1630 McCarthy Blvd
Milpitas, CA 95035
(408) 432-1900

Lutech
921 East 222nd Street
Euclid, OH 44123
(216) 731-8375

MX-Com
4800 Bethania Station Road
Winston-Salem, NC 27105
(800) 638-5577

Phaedra
PO Box 1241
San Bruno, CA 94066
(415) 359-0432

Player Piano
704 E Douglas
Wichita, KS 67202
(316) 263-3241

Play Meter
PO Box 24970
New Orleans, LA 70184
(504) 488-7003

RePlay
22157 Clarendon St Box 2550
Woodland Hills, CA 91365
(818) 347-3820

Shear-Loc
23191 Peralta Drive
Laguna Hills, CA 92653
(800) 775-5668

Silicon Systems
14351 Myford Road
Tustin, CA 92680
(714) 731-7110

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

Teltone
22121 20th Avenue SE
Bothell, WA 98021
(800) 426-3926

You can quickly and conveniently get copies of just about any technical standard from *Global Engineering Documents*. But note that it is often much cheaper to go directly to the standards associations themselves. We saw a full listing of these back in *Hardware Hacker #47* and in my on line and hard copy reprints.

Two rather strange and wondrous publications for this month are the *Iron-Man Album* and *Gas Engine*. For restorers of antique steam and gas powered tractors respectively.

If you want to start up your own tech venture, be sure to get a copy of my newly revised *Incredible Secret Money Machine II*. Check my nearby *Synergetics* ad for more info. Or send for a free brochure.

As usual, I've gathered most of the items mentioned into the *Names and Numbers* and *Multimedia Resources* sidebars. Always check these before calling our voice helpline.

Let's hear from you ❖

Don Lancaster's

Hardware Hacker

Hacker's data exchange
Adobe's Acrobat system
New pseudoscience mag
Voice messaging circuits
Special effects resources

January, 1994

Let's start off with a reminder that a superb video on using car alternators for low cost, high power stepper motors for CAD/CAM and whatever is now available from *John Rees*. Included is a demo of his sign routing system and step-by-step rewinding details. Cost of the vid is $19.50.

One hardware hacking topic which sure has generated more than its share of helpline calls lately involves…

Voice Messaging

At one time, analog tape cassettes seemed the only reasonable way to record and play voice messages. But these days, we've got compact, low power, and reliable total electronic solutions. Solutions which require no mechanical parts or moving media.

Uses? Everything from voice email systems to robotics to museum stuff to radio commercials to talking cards.

There are a lot of different options here. Options that trade quality and message time against costs, ease of recording, and compressibility.

Many older systems are based on *Toshiba* or *OKI* speech chips.

These systems are basically an A/D converter for recording, some digital storage, and output D/A analog sound processing circuits for playback. The digital storage could get permanently burned into certain chips as ROM or else easily changed as external RAM. But your usual route is to use a large EPROM for messages that are only to be changed every now and then.

Typical lower cost hacker systems here are the *Quik Voice* from *Eletech Electronics* and various offerings by *Ming Engineering*. Pricing is in the $20 to $40 range. These are usually a small circuit board holding a speech chip, a message EPROM, some analog circuits, and an output amplifier.

Everything from telephone up to CD quality is available by changing the sample rates. But your memory needs get out of hand for messages longer than a minute or so.

Two good starting points for this approach are the *Voice Synthesis LSI*

data book from *OKI* and various data books and ap-notes from *Toshiba*.

But there is a new kid on the block that offers a true single chip solution to electronic messaging. This one is called DAST, short for *Direct Analog Storage Technology*. Instead of going the A/D to digital storage back to D/A route, this new technique uses special circuitry that *directly* stores *analog* samples in a nonvolatile array.

The pioneer here is an outfit called *ISD*. Short for *Information Storage Devices*. Their current offerings are the ISD2500 family that gives up to 90 second playback at selected quality levels. As many as several hundred different messages can be stored. You could easily record a vocabulary of words and combine them as needed under external computer control.

Their analog storage capability is 480K, or just under half a meg. But do note that this is equivalent to many megabytes of pure digital storage.

ISD has also released a simpler and older ISD1000A chip through *Radio Shack*. This one costs around $20 for the chip alone and stashes 128,000 analog speech samples.

You will have to work up your own circuitry around it. Our figure one

shows an ultra simple playback-only circuit, while figure two shows you what is needed to record and play back your own messages.

There is no reason why you can't also use this for tones, sound effects, or short music. But note that the lower sampling rates of their DAST system pretty much will limit you to telephone quality.

A Hacker Data Format

Wouldn't it be nice if you could always get *exact sized* printed circuit layout artwork for popular magazine construction projects? With ongoing updates and corrections long after the story appeared in print? Or instant, low cost reprints for any tech article from anywhere? Reprints that look as good or better than the original? Or ready-to-use panel art, dialplates, or layout templates?

Well, I've been doing this for years with all of my more recent *Hardware Hacker*, *Ask the Guru*, *Resource Bin*, and *Blatant Opportunist* columns. By way of my *GEnie* PSRT. Plus lots of obscure stuff of mine which is *only* published on line.

But that is just me.

The key question here is: Which

Fig. 1 – PLAYBACK-ONLY CIRCUIT for the Radio Shack 276-1325 voice recorder. The ISD chip uses innovative on-chip analog data storage.

exact size is never guaranteed. And most fax files end up much longer and transmit much more slowly.

It turns out that FAX compression is just about the *worst* possible way to squash photos or fancy technical illustrations. See Adobe's note #5115 for unbiased comparisons. And it is still fairly tricky to store, edit, and reuse FAX code. And there's usually black and white only.

Yet, there are lots of others now offering tech info via automatic FAX services. For instance, *Dan Poynter* has some outstanding free resource info on self-publishing available by way of his auto FAX. And most of the electronic trade journals now have lots of auto FAX ads showing up.

On the other hand, PostScript can meet all of these hacker data goals. As I have mentioned a time or two before, I use PostScript as a totally *general purpose* computer language. I use it for everything from formal engineering design to stock market analysis. Plus, of course, dirtying up otherwise clean sheets of paper.

More and more hackers already do have easy access to a PostScript laser printer. If you do not, the *GhostScript* shareware is widely available for the downloading. This lets you run a fake PostScript over any popular printer, plotter, or phototypesetter. And yes, the full GhostScript source code is included so you can work from any recent host computer system.

One subtle but super important feature of PostScript: You can easily do *microsizing*. Which can let you precisely adjust your final size on printed circuit art, compensating for paper stretch or mechanical feeding errors. PostScript, of course, works beautifully with the new direct toner printed circuit processes offered by *DynaArt Designs* and *Techniks*. And, yes, PostScript could get converted back into into older and more klutzy *Gerber* or HPGL vector formats.

Adobe Acrobat is brand new. This is intended to let Fortune 500 firms achieve "paperless offices," whatever those are. Their fancy document files include global searching, nonlinear Hypercard access, and thumbnail sketches for each page. The system is quite expensive.

Sadly, Acrobat document files can *not* be printed without special viewer

Fig. 2 – A MULTI-MESSAGE COMBINATION playback and record circuit using the ISD1000A. An electret style microphone is shown.

data format could be used so that *all* authors of *all* technical mags could provide the same service?

There are several obvious goals for such a data format. The files should be totally device independent. The very same file should run identically on *any* personal computer, Mac, IBM, C-64, Amiga, Sun, or Cray. The files should consist of ordinary printable ASCII characters that can be sent over a non-transparent 7-bit data channel. There should be absolutely *zero* need for any special end user hardware or software. Files should be publishable on any and all popular printers.

The files should be more or less human readable and easy to edit. No royalties, costly software, limits, use licenses, or other restrictions should be involved. No trace should remain of any of the proprietary code used to generate the actual text and graphic images. All the files should also lend

themselves to full *Book-on-demand* publishing.

And, of course, the files should all be super compact and run quite fast. Self-collating at the max possible mechanical feed speed of the printer. With *zero* setup time. A reasonable goal is 10K per camera-ready page.

Uncompressed.

We'll assume that you are mostly interested in a *one way* publication. And getting superb quality copies of something into the hands of lots of people. Simply and cheaply.

After working on this problem for several years, I've concluded there are three routes to the hacker data format that seem reasonable. These are *FAX*, *PostScript*, or Adobe's new *Acrobat* document system.

I don't like FAX at all. I never use it. Special costly equipment is often needed. Compared to camera-ready PostScript, FAX quality is *putrid*. The

software. Acrobat files pretty much demand the use of genuine PostScript level 2. The final files are also much larger and run much more slowly than is really necessary.

Because nearly all of those more powerful PostScript commands are disallowed in the files, some simple graphic constructs will often generate unbearably long code. Ferinstance, a circle needs hundreds of bytes.

Something vastly better is clearly needed for a hacker file interchange standard.

The Solution?

Why not combine the best features of PostScript and Acrobat? Acrobat does contain a useable but grievously flawed *distillery* which can take any PostScript input from any source and reduce it to only those essential core commands. Usually (but not always) in a fairly efficient manner.

Sadly, the new distillery does all of its work in the host, rather than the printer. Any selected fonts must be available in host format. The file also has to be in one humongous piece, since persistent downloads and *run* support are appallingly absent.

Nonetheless, the distillery is the key to converting any code that was generated on a proprietary CAD/CAM, pagemaking, or illustration program and converting it into license-free and royalty-free distribution format.

Each page appears in the Acrobat document as an *object*. It is very easy to extract each page object, add some simple header code, and make it into a stand-alone PostScript file.

But I do feel that raw Acrobat page output is much too long and runs far too slow. It is also hard to read and harder yet to edit.

So, I have come up with a *triple distilling* process that dramatically improves extracted Acrobat files. The files are first split into their graphics and text portions. Then the graphic portions are shortened and simplified by permitting additional PostScript commands. The tricks used here will depend quite a bit on how the original code was first generated. But such operators as *repeat*, *translate*, and *arcto* can play a big role here.

The text is sorted so that *each font size only gets used once*. And defined such that *each text line stands on its*

```
/F8 1 Tf
9.75 0 0 9.75 60 427.5 Tm
0.029 Tc
0.032 Tw
(The tone frequencies are)Tj
/F9 1 Tf
10.9 0 Td
(subaural)Tj
/F8 1 Tf
3.7 0 Td
( in)Tj
-14.7 Te
0.021 Tc
-0.013 Tw
(that most phone or mobile comm gear)Tj
0 Te
0.043 Tc
0.115 Tw
(sharply attenuates audio below)Tj
9 0 0 9 200.4 406.5 Tm
0.046 Tc
0.124 Tw
(300)Tj
9.75 0 0 9.75 215.2 406.5 Tm
-15.9 Te
0.026 Tc
0.016 Tw
(Hertz or so.)Tj
1.025 Te
0.030 Tc
0.038 Tw
(The)Tj
9 0 0 9 89.1 385.5 Tm
0.032 Tc
0.041 Tw
(MX365A)Tj
9.75 0 0 9.75 125.4 385.5 Tm
0.030 Tc
0.038 Tw
( is a typical chip that)Tj
-6.7 Te
0.032 Tc
0.053 Tw
(can be be used either as the encoder)Tj
0 Te
0.032 Tc
0.053 Tw
(of Figure 2 or the decoder of Figure)Tj
0 Te
0.035 Tc
0.068 Tw
(3. This circuit offers your choice of)Tj
0 Te
0.048 Tc 0.148 Tw
(hardwire programmable tones or a)Tj
0 Te
0.038 Tc 0.084 Tw
(serial computer control. I've shown)Tj
```

Fig. 3 – TYPICAL ADOBE ACROBAT OUTPUT used to distribute high quality text and graphic documents. A special reader is needed at print time.

```
/Times-Roman 9.75 ss
.31 .29(The tone frequencies are)60 427.5 hH
( in)203.9 427.5 H
-.13 .21(that most phone or mobile comm gear)60 417 h
1.12 .42(sharply attenuates audio below)60 406.5 h
.16 .26(Hertz or so.)60 396 h
.38 .3(The)70 385.5 hH
( is a typical chip that)125.4 385.5 H
.52 .32(can be be used either as the encoder)60 375 hH
(of Figure 2 or the decoder of Figure)60 364.5 H
.67 .35(3. This circuit offers your choice of)60 354 h
1.45 .47(hardwire programmable tones or a)60 343.5 h
.82 .37(serial computer control. I've shown)60 333 h

/Times-Italic 9.75 ss
.31 .29(subaural)166.9 427.5 h

/Times-Roman 9 ss
1.12 .42(300)200.5 406.5 h
.38 .3(MX365A)89.2 385.5 h
```

Fig. 4 – TRIPLE DISTILLING can make the Acrobat output faster, shorter, and more hacker friendly. No expensive software or special printer is required.

SPECIAL EFFECTS RESOURCES

Alcone Company
5-49 49th Avenue
Long Island City, NY 11101
(718) 361-8373

14141 Covello Street Suite 6A
Van Nuys, CA 91405
(818) 782-9833

Cinefex
Box 20027
Riverside, CA 92516
(909) 781-1917

Cinema FX
13120-B Saticoy Street
North Hollywood, CA 91605
(818) 765-4995

Du-Bro Products
Box 815
Wauconda, IL 60084
(708) 526-2136

Electropea
24307 Magic Mtn Pkwy #272
Valencia, CA 91355

Film & Video
8455 Beverly Blvd Suite 508
Los Angeles, CA 90048
(213) 653-8053

Kryolan
132 Ninth Street
San Francisco, CA 94103
(415) 863-9684

Kuper Controls
11200 Montgomery, Suite 8
Albuquerque, NM 87111
(505) 263-5949

Makeup & Effects Lab
7110 Laurel Canyon Blvd Bldg E
North Hollywood, CA 91605
(818) 982-1483

Mannetron
74 Leonard Wood Drive
Battle Creek, MI 49015
(800) 357-2777

National Hair Technologies
300 Canal Street
Lawrence, MA 01840
(508) 686-2964

Polytek Development
Box 384
Lebanon, NJ 08833
(908) 534-5990

Quantel, Inc.
85 Old Kings Hwy North
Darien, CT 06820
(203) 656-3100

Smooth-On
1000 Valley Road
Gillette, NJ 07933
(908) 647-5800

Special Effects Supply Co
543 W. 100 North, Suite 3
Bountiful, UT 84010
(801) 298-9762

Mat Sweeney
14201 Bessemer Street
Van Nuys, CA 94101
(818) 902-9354

Sword & Stone
723 N Victory Blvd
Burbank, CA 91502
(818) 562-6548

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own. Unneeded characters (such as leading zeros, trailing spaces, and extra precision) are also eliminated to further shorten the files. The amount of speed and size gain here can be very impressive.

So much so that an *uncompressed* triple distilled file is often shorter than a compressed Acrobat file!

With some care, triple distilling can leave you with level 1 commands only, so that older PostScript printers can still be used. This will continue to be an important hacker feature for the next several years or so.

Figure two shows you a fragment of Acrobat text output, while figure three shows you the double distilled results. The Acrobat code is typically

65% longer and 43% slower. Besides being harder to read and edit.

Since many casual PostScript users end up horribly baud rate limiting themselves, a 65% length penalty can also become a 65% speed penalty.

More details in SPEEDUP.PS.

The triple distilling process can be fully reversable. The end user could always use the Acrobat distillery to get themselves right back where it all started. Or to import into packages that only accept limited PostScript commands. Such use would normally be very rare.

Custom or exotic fonts could get handled one of five ways: (1) You can ignore them and default to *Courier*. (2) You can ask your end user to get

all of his own fonts. (3) If only a few characters are involved, you can use a *font eliminator* that substitutes the actual font paths. This is great for logos. See FONTELIM.PS.

(4) You could use *multiple master* fonts for a lookalike approximation. Or, (5) You can internally tow along a copy of the needed font.

Yes, much of the triple distilling process can be fully automated.

If you do not have any access to Acrobat, there's an older DISTILL.PS file available for the downloading. This older program has lots of bugs that trash out clipping, scaling, and subscripting. But it can be run in any PostScript printer or emulator. It also supports persistent downloads, allows run commands, and has no host font restrictions.

I strongly feel that triple distilled PostScript is the ultimate solution for a compact and low cost hacker file interchange. I've got scads more on this up on *GEnie* PSRT, including lots of source code and examples.

Naturally, I'd be most happy to help you create your own distribution files in hacker data format. You can call or write for help on this.

Two Contests

As the first of our two contests this month, just tell me your thoughts for a new hacker data format standard. There'll be all of the usual *Incredible Secret Money Machine* books going to 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 written entries directly to me here at *Synergetics* and not to **Electronics Now** editorial.

Special Effects

How would you like to build your own T-Rex? Or shoot your custom version of *Godzilla versus the Night Nurses* as a home video? What you'll require for this, of course, are *special effects*. As you might guess, there is a low profile and little known special effects industry. Who can supply all of your needed bits and pieces. Either off-the-shelf or custom.

The special effects supply sources can be a treasure trove for hardware hacking. Included are materials for plastic, rubber, and resin molding.

Special hardware. Unusual materials. Claymation supplies. Fur and hair. Armatures. Control cables. Remote controls. Unusual lighting. Fog and smoke. And lots more.

As our sidebar for this month, I thought we'd gather together a few of the better special effects resources. The center of the industry appears to be a great quarterly magazine called *Cinefex*. A recent issue showed the insider secret plans to all the Jurassic dinos, as well as the Andean plane crash. A second useful mag here is *Film & Video*.

Two of the more intriguing entries on our list are the *Sword & Stone* and *National Hair Technologies*. The first for medieval armor, and the second for fake fur and strange wigs.

There are a lot more where these came from, so be sure to let me know your favorites. Or anyone I missed.

In fact, let's make a second contest out of it.

New Tech Lit

Untapped Technology in Review is a new labor-of-love pseudoscience journal. Uh, this one seems midway between the *Skeptical Inquirer* and and the *Borderlands Quarterly*.

Included are commented critical reviews of some popular free energy and antigravity schemes, the current contents for the other pseudoscience mags, and off-the-wall patent listings.

A brand new book on buying and using older *Tektronix* oscilloscopes is titled *Oscilloscopes: Selecting and Restoring a Classic*. This one costs $19.95 from *Stan Griffith*.

Olympus has just introduced their *Videoimagescope* systems. This is a full color video camera a *quarter inch* in diameter at the end of a 70 foot (!) strobe-illuminated and fully steerable snake-like probe.

While this dude looks outrageously expensive, it just might make a really dandy cave survey and exploration tool. Especially if it could be made self-cleaning and waterproof to a depth of twenty feet.

The horse's mouth source info on SCSII disk comm is known as ANSI X3.131-1986 and is available for $50 directly from the *American National Standards Institute*

Sound Practices is a hands-on mag that concentrates on tube audio using

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NAMES AND NUMBERS

Adobe Acrobat System
1585 Charleston Road
Mountain View, CA 94039
(800) 833-6687

Am. Natl. Standards Institute
11 West 42nd Street, 13th Floor
New York, NY 10036
(212) 642-4900

Borderlands
PO Box 429
Garberville, CA 95542
(707) 986-7211

DynaArt Designs
3535 Stillmeadow Lane
Lancaster, CA 93536
(805) 943-4746

Eletech Electronics
16019 Kaplan Avenue
Industry, CA 91744
(818) 333-6394

GEnie
401 North Washington Street
Rockville, MD 20850
(800) 638-9636

Gerber Scientific
83 Gerber Road
S Windsor, CT 06074
(203) 644-1551

Stan Griffiths
18955 SW Blanton
Aloha, OR 97007
(503) 649-0837

Information Storage Devices
2841 Junction Avenue, Ste 204
San Jose, CA 95134
(408) 428-1400

Ming Engineering
17921 Rowland Street
City of Industry, CA 91748
(818) 912-9469

OKI
785 North Mary Avenue
Sunnyvale, CA 94086
(800) 832-6654

Olympus Industrial
4 Nevada Drive
Lake Success, NY 11042
(800) 446-5260

Dan Poynter
PO Box 4232
Santa Barbara, CA 93140
(800) PARAPUB

John Rees
Route 1 Box 1551
Sautee, GA 30571
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Skeptical Inquirer
PO Box 703
Buffalo, NY 14226
(716) 636-1425

Sound Practices
Box 180562
Austin, TX 78718
(512) 339-6229

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

Techniks
45 J Ringo Road
Ringoes, NJ 08551
(908) 788-8249

Toshiba
1220 Midas Way
Sunnyvale, CA 94066
(800) 321-1718

Untapped Technology Review
PO Box 5185
Mesa, AZ 85211

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only high voltage linear triodes. The preferred tube these days seems to be the 211. To me, that mythical "tube sound" is simply so much hum, noise, and distortion added to an otherwise clean audio channel.

You can easily pick up any amount of hum, noise, and distortion by using a digital signal processing chip and a decent DSP algorithm. And be able to do so even for vacuum tubes that have not been invented yet.

For more info on PostScript, use Adobe's *Red* and *Blue* books, and my *PostScript Secrets* book/disk combo.

Or, to really jump in with both feet, our *Whole Works* package offers one each of everything needed to learn PostScript by all major authors at a substantial savings. See my nearby *Synergetics* ad for more info.

Lots of ready-to-use PostScript files also appear on *GEnie* PSRT.

Our usual reminder that most of the sources mentioned appear either in the *Names & Numbers* or the *Special Effects Resources* sidebars. Be sure to check here first before you call our no-charge helpline.

Let's hear from you. ❖

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