Don Lancaster's **Tech Musings**

June, 2000

any of the formulas you'll find in electronics books are oversimplifications of all the vastly fancier math behind what is really coming down. These simple formulas can get you in trouble should you try to use them without understanding their limits.

We have already seen in previous columns how power measurement is *never* the average volts times average amps. And how voltmeter-ammeter methods often lie like a rug. Severely *under*reporting when low duty cycles or strange waveforms are involved. Or misleadingly *over*reporting when ac reactance lead or lag phase angles are present. Check out MUSE112.PDF and MUSE113.PDF in particular for more power measurement secrets.

Another advanced concept that can cause you considerable grief is...

Understanding Nonlinearity

A *linear system* is one in which, if you double your input, you'll double your output. And separate inputs will give separate *superpositioned* outputs which do not interact with each other in any way. Linear systems are often assumed in most electronics math.

Sadly, *real-world linear systems do not exist*. Instead, there are *always* behavior deviations of one stripe or another, introducing mild to severe *nonlinearity*.

Often, the inevitable nonlinearities are small enough that you can ignore them. Other times they may not be.

Your electronic rules all change in the presence of strong nonlinearity.

For instance, if you take a resistor and apply a sane voltage, you should measure some current by Ohm's law. Double the voltage and your current also should double.

Now, select any silicon diode and briefly apply 0.4 volts in its forward direction. Measure the current. When you double this voltage, you will get a current that is *thousands of times* higher than before. Why? Because a diode is a classic nonlinear device. Similarly, if you apply one volt dc to a water electrolysis cell, you will measure a relatively weak current. Double it and the current increases by hundreds or thousands of times.

Just like a diode.

Yes, Ohm's Law is still valid. But the resistance now *depends* upon the voltage or current you apply, rather than being some constant. Which is a basic definition of nonlinearity.

Let us look at two useful tools for dealing with nonlinearities. The first of these involves...

Using Transfer Functions

A transfer function or a response curve can be used to show the output to input ratio of nearly any "history free" physical system, linear or not. In electronics, transfer functions can relate the voltage in to a voltage out, current in to voltage out, voltage in to current out, or current in to current

Algae hydrogen source Applying Taylor Series Surplus & auction update Lithium polymer batteries Understanding nonlinearity

out. Depending on the device.

Transfer functions can often get calculated or measured. They can be based upon observed numbers, upon theoretical math functions, on plotted graphs, or be any combination of the three. The automatic generation of suitable graphs is sometimes called *curve tracing*.

Let's look at a subtle example that seems to be causing untold grief both on the web and in the patent office.

Figure one shows us the very low frequency transfer function of a cell used for hydrogen electrolysis. If you remain under the threshold of 1.28 volts, only your solution conductivity will contribute to the current drawn. Above the threshold, more and more current gets drawn by the electrolysis gas production itself.

Curiously, the electrons you'll get



Fig. 1 – A TRANSFER FUNCTION can relate the output to the input of any history-free physical system. In this low frequency hydrogen cell, extreme nonlinearity redistributes the spectral energy.

148.1

Tech Musings



Fig. 2 – TAYLOR SERIES deals with nonlinearity by breaking a curve down into separate terms.

back are *not* the ones that you sent out. Your outgoing electrons convert hydrogen ions into hydrogen atoms. Your incoming electrons will convert oxygen ions to oxygen atoms. But at your terminals, any electron looks like any other electron.

Since any overvoltage above your threshold sharply increases both the current and the gases liberated, your transfer function is somewhat similar to a diode or zener and thus ends up remarkably nonlinear.

Suppose you apply a dc biased low ac frequency to this cell. What will the current look like?

Mathematically, you can multiply your instantaneous voltage times the transfer function to get your output current. Graphically, you can simply "bounce off" the curve, sending the voltage in on the x voltage axis and reading the current you get out the y current axis.

We see that we input a nice clean voltage offset sinewave. But we get a very nonlinear series of quite narrow current pulses out. When you analyze these pulses by using Fourier Series (details in MUSE90.PDF), you'll see a strong dc term, lots of useless high harmonics, and very little remaining fundamental sinewave energy!

Note that the narrow current pulses have rms values which are *very much higher* than their average value. Note







Fig. 3 – NEW LITHIUM POLYMER rechargable batteries can give you one ampere hour of storage in a credit card sized package.

also that the useful portions of your power pulses will be even narrower.

This is your usual source of wildly understated power measurements.

There is at least one patent which claims that some audio or ultrasonic sinewaves might "resonate" a water molecule. For a dozen solid technical reasons, I personally feel this fantasy is totally bogus.

Not the least of which is that the nonlinear cell *immediately changes* most any voltage sinewave input to a strong dc term which does a normal electrolysis. Plus a bunch of useless harmonics that most likely contribute only to cell heating.

The cell capacitance effects should even further significantly reduce both the fundamental and harmonics.

Now yes, a *mechanical* sonic wave might be able to shake some bubbles loose or maybe sonoluminesce, or do something similar. Possibly for some modest efficiency gain. But these are completely different and acceptable "real science" effects.

If you really wanted to prove there was a highly unlikely process such as electrically driven audio frequency water resonance, you would have to use input *current* waveforms instead. Why? Because the cell's nonlinearity trashes input voltage waveforms!

Taylor Series

There is a useful math tool known as *Taylor Series* that can be handy to deal with nonlinearities. Major or minor.

June, 2000

Suppose, as in figure two, you've got a "bent" waveshape. Near a value of interest, you could use that value as a *zero order approximation*.

Mathematically, we can say...

$$f(x) = a_0$$

...or that it is everywhere the same. Which is about as useful as a stopped clock that is right twice a day. But, hey, it's a start.

Chances are your waveshape will have some non-horizontal *slope* at a point of interest. Thus, for our *first order approximation*, we'll draw a straight line through that slope at our a_0 point...

$$f(x) = a_0 + a_1 x$$

This is a classic linear system with offset. You can think of a_0 as the *dc* offset, and a_1 as your gain. Negative gain values mean there is a polarity or phase inversion. Gain values that range between +1 and -1 might be interpreted as *loss* or attenuation.

This linear approximation will end up exact at one point and pretty good nearby. To try and correct the errors that are further out, we add a *second order* term to our series...

$$f(x) = a_0 + a_1 x + a_2 x$$

In other words, we try to add in a little piece of a parabola to our fitting process. This square term is the first nonlinear one. And it often will do nasty or ugly things. Ferinstance, a square term will *multiply* an input by itself. Worse yet, it might multiply all of the inputs together. Either of these leads to harmonics, distortion, spurs, and other new frequencies that were not present in the input.

Proof of this can be found on the *trigonometric identities* page of any trig book. *Add* two sinewaves and they'll remain the same. But if you *multiply* any two sinewaves together, you'll get lots of *sum* and *difference* frequencies. Square a sinewave and you get double frequency and other more exotic terms.

The second order Taylor term may end up "good enough" for analyzing amplifier distortion or correcting the response of a thermocouple or other real world sensor.

If a second order approximation is not good enough, you can add a new cubic term, a quartic, and so on. In

% POSTSCRIPT MATH FUNCTION UTILITIES

- Copyright c 2000 by Don Lancaster and Synergetics, Box 809, Thatcher, AZ, 85552
- % (520) 428-4073 don@tinaja.com website: http://www.tinaja.com
- % Consulting services available per http://www.tinaja.com/info01.html
- % All commercial rights and all electronic media rights fully reserved.
- % Personal use permitted provided header and entire file remains intact.
- % Linking welcome. Reposting expressly forbidden.
- % These PostScript-as-language routines show you how to generate two useful
- % math functions, namely a swept sinewave and a classic narrow pulse.
- % To use this program, move the modules into your code, reposition as needed
- % and then distill the file. Or send the file to GhostScript.



/sinxx {gsave translate -1000 240 div -1000 sin -1000 div 300 mul -1000 10 div cos mul moveto -1000 3 1000 { dup 0 eq {pop 0.0001} if /val exch def val 240 div val sin val div 300 mul val 10 div cos mul lineto} for line1 stroke grestore} def



/chirphscale 1 8 div def /chirpvscale 2 def /sweeprate 0.3 def

/chirp {gsave translate newpath 1 setlinejoin -70 chirphscale mul -70 dup mul cos chirpvscale mul moveto -70.4 .1 70.4 { /val exch def val chirphscale mul val dup mul cos chirpvscale mul lineto} for line1 stroke grestore} def

%%%% demos - remove before use %%%%%

100 100 translate	% position on page
0.1 dup scale	% select size
16 21.2 chirp	% create swept waveform
16 7.2 sinxx	% create sinx/x pulse
showpage	% and show the page
%% EOF	

Fig. 5 – POSTSCRIPT CODE to generate fancy math functions.

general, *even* terms will do the *same* thing on either side of the zero point, while *odd* terms will do the *opposite*.

Odd terms thus add *assymetry*.

It turns out that *higher order* terms should be more effective *away* from your zero reference, while the *lower order* terms can have more results *near* your zero reference.

Normally, the *higher order* Taylor terms will be quite small and may not be needed at all.

At any rate, you use as much of a "full" Taylor Series as you need...

$$f(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + \dots + a_n x^n$$

Taylor series lets you approximate many real world responses. You can find your first n Taylor series terms from your data plot. Evaluate the plot at n+1 points. Then you solve n+1equations in n+1 unknowns. This gives you a_0 through a_n We saw an example in MUSE142.PDF

Note that the Taylor terms form a linear system. Thus, you can largely deal with each individual Taylor term on it own. Note also that the Taylor Series and the transfer functions can be combined.

Lithium Polymer Batteries

The "next big thing" in rechargable batteries may use *lithium polymer* technology. Figure three shows us a new example from *UltraLife*.

These can offer energy densities of 125 Watt Hours per Kilogram and 250 Watt Hours per liter. A typical



Tech Musings

SOME BATTERY TECHNOLOGY BOOKS

Battery Reference Book (Thomas Crompton) Battery Technology Handbook (H.A. Kiehne) Electric Hybrid Vehicles ... BatteryTechnology (SAE) Electric Vehicle Battery Systems (Sandeep Dhameja) Electrochemical Cell Design (Ralph White) Electrochemical Power Sources (M. Barak) Electrochemical Supercapacitors (B. E. Conway) Electrochemistry of Novel Materials (Jacek Lipkowski) Fuel Cell Systems (Leo Blomen) Handbook of Batteries (David Linden) Handbook of Battery Materials (Jurgen Besenhard) Hydrogen & Metal Hydride Batteries (P. D. Bennett) Lithium-Ion Batteries (Masataka Wakihara) Lithium Polymer Batteries (J. Broadhead) Modern Batteries: Intro to Electrochemical... (C. Vincent) New Materials for Batteries and Fuel Cells (D. Doughty) Practical Photovoltaics (Richard J. Komp) RVer's Guide to Solar Battery Charging (Noel Kirkby)

For more book details, see www.tinaja.com/amlink01.html

three volt and one ampere hour cell might measure two inches by three inches by a tenth of an inch thick.

Their cycle life now exceeds 300 charge/discharge cycles. There is no "memory effect" common to heavier Nicad batteries. Prices do remain a tad high. But are certain to drop as the learning curve falls and volume continues to ramp up.

Because most batteries involve the movement of only one electron per atom, your lightest elements (such as lithium) would seem to be your best choice to maximize your watt hours per kilogram density. A key problem has been getting violently reactive lithium to behave well enough to be safe for consumer products.

Extreme caution is needed when you charge a lithium battery. Special chips that monitor voltage, current, and temperature are a must. Initial charging of a nearly empty cell *must* be very gentle. One good choice for single cell charging is the *Maxim* MAX1679 of figure four.

Be certain to read that Maxim data sheet very carefully, for there are a few subtle gotchas. Not the least of which is that your input dc current must be externally current limited to your maximum fast charging rate! Typically, you'll handle this with a 6 volt, 600 milliampere wall wart. Your optional LED has four modes: On for fast charge, weakly blinking for full charge maint, strongly blinking for a fault, or off for no battery present or lack of input power.

Evaluation kits are obtainable by way of *www.maxim-ic.com* There's also some fancier versions, such as the multi-cell MAX1645.

Some Battery Books

One free resource is that *Battery Power Products & Technology* trade journal you should locate online at *www.infowebcom.com* Very useful alternate energy battery info appears in *Home Power Magazine* and their recently released *Solar CD IV*.

Some more scholarly pubs include Advanced Battery Technology, the Battery and EV Technology, and CA Selects: Batteries & Fuel Cells. Lots of other related links are found at my

NEED HELP?

Phone or email all your US Tech Musings questions to:

> Don Lancaster Synergetics Box 809-EN Thatcher, AZ, 85552 (520) 428-4073

US email: *don@tinaja.com* Web page: *www.tinaja.com*

http://www.tinaja.com/h2gas01.html

I've gathered some of the better and newer battery books together for you as this month's resource sidebar.

Plotting Real Functions

As much as possible, I try to use the "real" math in most of my figures and illustrations. Ferinstance, the bat comm in last month's figure four is generated from a swept sinewave and a sinx/x pulse.

PostScript-as-langauge, of course, makes this trivial. As our PostScript utility example for this month, I've excerpted and modified slightly the figure four code needed to generate these two useful math functions.

As usual, you will first enter your PostScript code into a word processor or editor, modifying it to suit your needs. Then, be certain to save your file *as an ordinary ASCII textfile*. Do *not* use your custom word processor format. You then send this file to a host based Acrobat Distiller.

Or, optionally, to *GhostScript* or to a PostScript speaking laser printer.

More PostScript-as-langauge is in *www.tinaja.com/post01.html* and in *www.tinaja.com/acrob01.html*. Ready to run figure four code can be found in file MUSE147.PSL.

By the way, the nonlinear function I happened to actually use in figure one is the partial Taylor Series...

 $y = 0.15x + 2.00x^6$

... over an x range of 0 to 1. This seems to give a fairly good low frequency approximation to the real world response of a typical cell. But almost certainly does *not* reflect the true underlying physics.

Which should consist of an IR ion conduction term and a nonlinear 1.28 volt thresholded gas generation term. As I mentioned a time or two before, the definitive SPICE model for a H_2 electrolysis cell still seems to remain conspicuously absent.

And is sorely needed.

Surplus Auction Update

The feds are now in the process of privatizing many of their mil surplus sales. Driven by admin costs that are much *higher* than their typical sale income of 0.7 cents on the dollar. The fed-run sales that remain can still be reached by clicking on those DRMS

148.4

Copyright c 2000 by Don Lancaster and Synergetics (520) 428-4073 www.tinaja.com All commercial rights and all electronic media rights fully reserved. Reposting is expressly forbidden.

NAMES AND NUMBERS

Adobe Systems PO Box 7900 Mountain View CA 94039 (800) 833-6687 www.adobe.com

Advanced Battery Technology 913 Tressler Street Boalsburg PA 16827 (814) 466-6559 www.sevmtnsci.com

Auction Advisory Box 61104 Phoenix 85082 (602) 994-4512 www.auctionadvisory.com

Battery & EV Technology 25 Van Zant Street #13 Norwalk CT 06855 (203) 853-4266 buscom2@aol.com

Battery Power Online 7355 E. Orchard Road Ste 100 Englewood, CO 80111 (800) 803-9488 www.infowebcom.com/battery

CA Selects: Batteries PO Box 3012 Columbus OH 43210 (800) 848-6538 www.cas.org

e.bill 2424 American Lane Madison WI 53704 (608) 241-8777 www.ebillmag.com

Home Power PO Box 520 Ashland OR 97520 (916) 475-3179 www.homepower.com

Industrial Laser Solutions PO Box 21288 Tulsa OK 74121 (800) 752-9764 www.industrial-lasers.com

buttons on my home page.

A commercial outfit by the name of *Levy-Latham* has now taken over many of these military surplus sales. Reach them at *www.levylatham.com* or by clicking the LEVYLAT button on my home page. They currently do offer sealed bid plus live auctions, private treaty sales, pack-ship info, *eBay* auctions, online sales.

Your best source for live auction info remains *Auction Advisory* found at *www.auctionadvisory.com* You can also click on that AUCTADV button on my home page. These people are

LBS

PO Box 1413 Des Moines IA 50305 (800) 247-5323 www.lbsbind.com

Levy Latham 6263 N Scottsdale Rd Ste 371 Scottsdale AZ 85250 (480) 367-1100 www.levylatham.com

Lindsay Publications PO Box 538 Bradley IL 60915 (815) 935-5353 www.lindsaybks.com

Maxim 120 San Gabriel Dr Sunnyvale CA 94086 (800) 998-8800 www.maxim-ic.com

Science/AAAS 1333 H St NW Washington DC 20005 (202) 326-6400 www.sciencemag.org

Spread Spectrum Scene PO Box 2199 El Granada CA 94018 (800) 524-9285 www.sss-mag.com

Synergetics Box 809 Thatcher AZ 85552 (520) 428-4073 **www.tinaja.com**

Test Equipment Connection 525 Technology Park Lake Mary FL 32746 (800) 615-8378 www.4testequipment.com

Ultralife Batteries, Inc. 2000 Technology Parkway, Newark, NY 14513 USA (315) 332-7100 www.ulbi.com

now nationwide, having some 75,000 live auctions published to date.

I've found I get the best results in obscure, remote, and lousy weather auctions. Especially when I'm the only bidder at a site where the tech goodies are only a non-obvious and very minor part of what is being sold. Community college auctions seem particularly productive for me.

Because auctions are typically an extremely inefficient market, lowball bidding on twenty times what I could possibly use and taking a five percent success rate makes a lot of sense to

new from DON LANCASTER

ACTIVE FILTER COOKBOOK

The sixteenth (!) printing of Don's bible on analog op-amp lowpass, bandpass, and highpass active filters. De-mystified instant designs. \$28.50

RESEARCH INFOPACKS Don's instant cash-and-carry flat rate consulting service. Ask any reasonable technical question for a detailed analysis and complete report. See www.tinaja.com/info01 for specifics. \$79.00

CMOS AND TTL COOKBOOKS Millions of copies in print worldwide. THE two books for digital integrated circuit fundamentals. About as hands-on as you can get. **\$28.50** each.

> INCREDIBLE SECRET MONEY MACHINE II

Updated 2nd edition of Don's classic on setting up your own technical or craft venture. **\$18.50**

LANCASTER CLASSICS LIBRARY

Don's best early stuff at a bargain price. Includes the CMOS Cookbook, The TTL Cookbook, Active Filter Cookbook, PostScript video, Case Against Patents, Incredible Secret Money Machine II, and Hardware Hacker II reprints. \$119.50

LOTS OF OTHER GOODIES

Tech Musings V or VI	\$24.50
Ask the Guru Lor II or III	\$24.50
Hardware Hacker II. III or IV	\$24.50
Micro Cookbook I	\$19.50
PostScript Beginner Stuff	\$29.50
PostScript Show and Tell	\$29.50
PostScript Video & secrets	\$29.50
PostScript Reference II	\$34.50
PostScript Tutorial/Cookbook	\$22.50
PostScript by Example	\$32.50
Understanding PS Programming	\$29.50
PostScript: A Visual Approach.	\$22.50
PostScript Program Design	\$24.50
Thinking in PostScript	\$22.50
LaserWriter Reference	\$19.50
Type 1 Font Format	\$16.50
Acrobat Reference	\$24.50
Whole works (all PostScript)	\$380.00
Technical Insider Secrets.	FREE

BOOK-ON-DEMAND PUB KIT

Ongoing details on Book-on-demand publishing, a new method of producing books only when and as ordered. Reprints, sources, samples. **\$39.50**

THE CASE AGAINST PATENTS

For most individuals, patents are virtually certain to result in a net loss of sanity, energy, time, and money. This reprint set shows you Don's tested and proven real-world alternatives. **28.50**

BLATANT OPPORTUNIST I

The reprints from all Don's Midnight Engineering columns. Includes a broad range of real world, proven coverage on small scale technical startup ventures. Stuff you can use right now. **\$24.50**

RESOURCE BIN I

A complete collection of all Don's Nuts & Volts columns to date, including a new index and his master names and numbers list. \$24.50

FREE SAMPLES

Check Don's Guru's Lair at http://www.linaja.com for interactive catalogs and online samples of Don's unique products. Searchable reprints and reference resouces, too. Tech help, hol links to cool sites, consultants. email: doir@/linaja.com FREE US VOICE HELPLINE VISA/MC

SYNERGETICS Box 809-EN Thatcher, AZ 85552 (520) 428-4073

Tech Musings

me. As does heavy dumpster triage. (ac linecords with a 386 computer attached are *much* cheaper than the linecords by themselves!) One little known insider bidding secret: You can often cut your next bid increment in half simply by waving your hand horizontally across your chest.

Palm down.

The trick, of course, is to buy for a penny on the dollar, sell for a dime on the dollar, and try to make a nine precent profit in the process. Be proud to be a bottom feeder.

The closest approach to a used test equipment "blue book" seems to be the free catalog from *Test Equipment Connection* that you should pick up at *www.4testequipment.com*.

Divide their list prices by *five* to get a typical *eBay* price, by *eight* to get a fair hamfest price, and by *thirty* to get a sane bid on a mil surplus skidded lot. I rarely bid over 0.3 cents on the dollar on mil auctions.

Note that *Hewlett Packard* and *Tektronix* overwhelmingly dominate the used test equipment market. With a very few *Wavetek*, *Fluke*, or ancient *GR* exceptions, anything else is likely to end up high risk.

See www.tinaja.com/resbn01.html

I have test equipment bargains up at www.tinaja.com/barg01.html or by clicking on that AUCTION button on my website at www.tinaja.com

New Tech Lit

The first really new thermoelectric material in three decades is described in *Science* for February 11, 2000 on pages 945+ and 924+. Although still incomplete and not more efficient than previous abysmal TE offerings, this just may be able to significantly extend thermoelectrics to amazingly low cyrogenic temperatures.

As well as reawakening a stagnant field of research.

A sneaky ploy to trick algae into generating hydrogen appears in the Jan 2000 issue of *Plant Physiology*. Authored by Melis, Zhang, and a few others on pages 127-136 The free abstract is at *www.plantphysiol.org*

Be sure to try and scam one of the free *Microchip Technology* "over one billion sold" pr promo kits. Without my giving away the punch line, let's just say that their mailing tube uses an amazingly advanced technology.

Our three featured trade journals for this month are Randy Roberts' *Spread Spectrum Scene*, an *Industrial Laser Solutions*, and the new *e.bill* covering internet online payments.

The latest in "old-new" books from Lindsay Publications are a 1944 pub titled as High Frequency Induction Heating and his Lead Acid Batteries text. Reach them from their banner on my website. For your own banner, see *www.tinaja.com/advt01.html* or my BANNYEAR.PDF tutorial.

Freebie samples of laser printable hardback book cover materials are offered by *LBS*. They also publish a *Cover to Cover* newsletter. More on Book-on-demand publishing help is in *www.tinaja.com/bod01.html*

Several useful consulting websites are at www.freeagent.com, guru.com, www.expertcentral.com and my own www.tinaja.com/consul01.html and www.tinaja.com/info01.html

Contacts and pubs on underground cave radio comm can be gotten at *www.sat.dundee.ac.uk/~arb/creg*

For all the fundamentals of digital integrated circuits, do check into my *CMOS Cookbook* and *TTL Cookbook*. Either by themselves or as part of the bargain priced *Lancaster Classics Library* per my *Synergetics* ad.

Be sure to look into my low cost consulting services you will find at *www.tinaja.com/info01.html*, surplus bargains up at *www.tinaja.com/barg 01.html*, and banner advertising opps at *www.tinaja.com/advt01.html*

As usual, most of the mentioned references do appear in our *Names & Numbers* or *Battery Books* sidebars. These are available hotlinked as my file MUSE148.PDF. Be sure to check here first before you email me at my *don@tinaja.com* or calling the US tech helpline shown in the box. \blacklozenge



