Don Lancaster's

Tech Musings

May, 1997

Several column corrections
Power measurement basics
New aerogel developments
Understanding rms currents
Telephone extension lockout

Did I say that? Note that those brand new baby PIC's from *Microchip Technology* have *highly* unusual supply pins. Especially for an eight pin minidip. Your positive supply of a PIC12C508 or a PIC12C509 goes to pin *one*. And *ground* goes to minidip pin *eight*.

It is trivially easy to overlook the obvious. View a Vee-sub-something-or-other where you seem "certain" to expect the positive supply. And away you go. You've been had.

Well, on these chips Vee-sub-dee-dee (V_{DD}) is their positive supply pin. Vee-sub-ess-ess (V_{SS}) gets grounded. The supposed "rules" of "highest pin is positive" and "diagonally opposite pin is ground" are clearly violated.

Naturally, you should *always* and *carefully* read the *exact* data sheet to make sure of all pinouts. Especially before powering up your chip or even starting your pc layout.

At any rate, figure one of my Tech Musings column #108 had the baby PIC pins backwards. I have corrected this in MUSE108.PDF and in my *Tech Musings* reprints.

Sorry about that.

An older part which might create similar grief over bass ackwards pins is that *National* LM324 quad op amp. Your *positive supply* goes to *low* pins number *four*. Ground routes to *high* pins number *eleven*.

Measuring Power

It is amazing how much trouble people can get themselves into when they don't have the foggiest clue how to make the most fundamental of ac power measurements. Especially as beginning lab students or whenever making absurdly wrong claims about circuit efficiencies.

If you try to measure ac or pulse circuit power using a voltmeter and an ammeter, your results will nearly always be *utterly wrong*. Especially when phase shifts, harmonics, or any unusual waveforms are involved. It is trivially easy to create errors of 400 percent or higher. And *never* in your favor, of course.

The fundamental equation appears simple enough…

watts = *volts* x *amps*

To find your power, you multiply your volts times your amps, right?

Wrong.

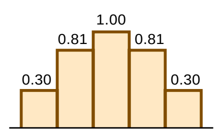
This equation *only* will work when you multiply *instantaneous* voltage times *instantaneous* amperage. Your volts and amps *must* be in the same place at the very same instant. They *must not* change while you are doing the measurment.

Your *only* correct way to measure power is to multiply an instantaneous voltage times instantaneous current. Measured over some *very brief* time increment. Then, you sum all of these incremental measurements to find the longer term *average power*.

Finally, you'll ask what *equivalent continuous dc current* you'd need to produce an *identical* value of average power. This equivalent continuous dc current is also called the *rms* current, short for *root-mean-square*.

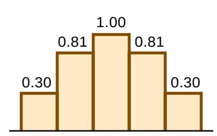
Circuits are the easiest to analyze when you *normalize* them. Let's start with a simple case. Assume we have a one ohm purely resistive load. With a one ohm load, the rms current will

The **AVERAGE CURRENT** of a waveform is found as you would find any other average. Take narrow samples. Add each sample value, then divide by the number of samples. Here is a five step approximation to a half sinewave…



average current = (0.30 + 0.81 + 1.00 + 0.81 + 0.30)/5 = 0.65

The **AVERAGE POWER** of a waveform driving a one ohm resistive load is found by squaring the curent of each sample and summing them...

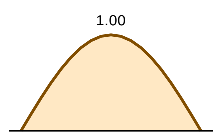


average power = $((0.30)^2 + (0.81)^2 + (1.00)^2 + (0.81)^2 + (0.30)^2)/5 = 0.50$

The **RMS CURRENT** of a waveform is the equivalent dc current you'll need to produce the same average power. For a one ohm resistive load, RMS current is found by taking the square root of the average power…

$$\text{RMS current} = \sqrt{\text{average power}} = \sqrt{0.50} = 0.71$$

For more accuracy, calculus integration is often used instead…



$$\text{average current} = \frac{1}{\pi}\int_0^{\pi} \sin(\theta)\,d\theta = 0.637$$

$$\text{average power} = \frac{1}{\pi}\int_0^{\pi} \sin(\theta)^2\,d\theta = 0.500$$

$$\text{rms current} = \sqrt{0.500} = 0.707$$

Average current is highly wave shape dependent. Average current often will be a grossly misleading and totally useless way to try and measure circuit power. For accurate results, true rms measurements must **~always~** be made.

Fig. 1 – THE RMS CURRENT of any waveform is the exact equivalent amount of continuous current you have to apply to get the same average power.

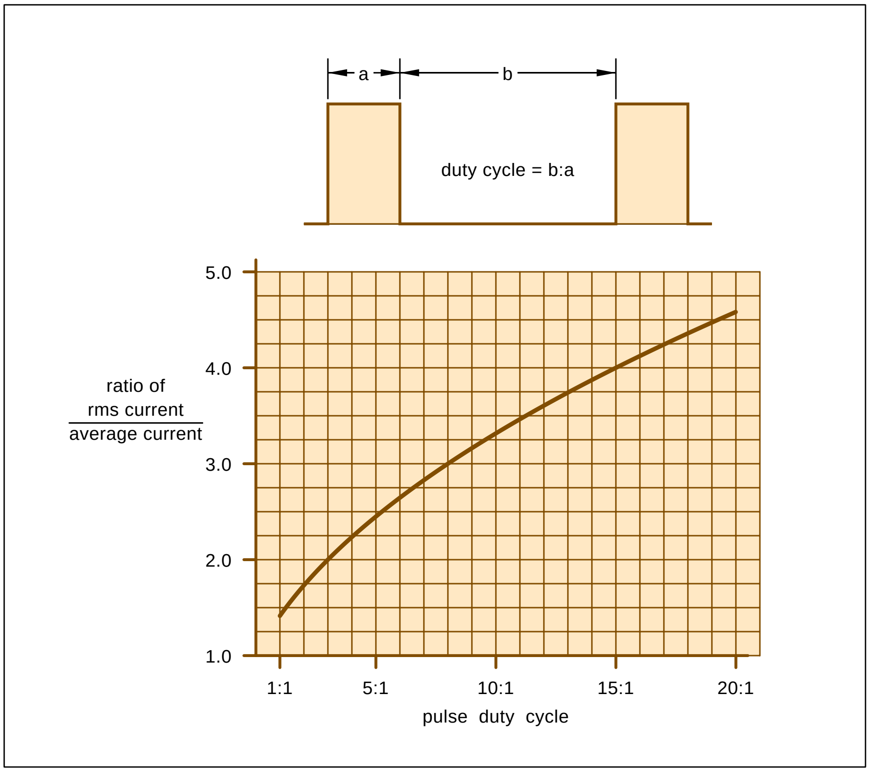


Fig. 2 – LOW DUTY CYCLE PULSES may involve surprisingly low average currents. Their power can ~only~ be measured by using premium "true rms" instruments. Ordinary panel meters and VOM's are all average responding. Giving you absurdly low results that are ~certain~ to be dead wrong.

equal the *square root* of the average power. By Ohm's law.

Lets further assume we have a low distortion ac source which is a pure fundamental frequency sinewave. Let us work with a positive half cycle of that sinewave.

Figure one shows us how we can crudely approximate a half sinewave using five rectangular steps. We take each step's current and average it. To get the average current of 0.65.

Next, we sum the currents *squared* to find each step's power. And then we divide by five to find the average power. We take the square root of the average power to get the rms current of 0.71. For this waveform.

Two numbers which seem "purty nigh but not plumb".

If we use more steps, we can get closer to the "real" answers. There's a neat-o math stunt known as *integral calculus* that can let you sum up an infinite number of infinitely narrow steps. Giving us the "real" answers of a sinewave having an average current of 0.637 peak and its rms current of 0.707 peak value.

See any old intro ac circuit theory book for full details.

Plain old analog ac panel meters measure an *average* current. These will wrongly *assume* that you *always* have a continuous and low distortion fundamental frequency sinewave.

And simply fudge their results by multiplying all meter readings times 1.11072. A number that *only* relates the ratio of the average current and rms current of a clean half sinewave.

And is otherwise wildly *low*.

Three Mistakes

There are three usual mistakes that most beginners make here:

assuming the voltage and current are in phase– Voltage and current will be in phase *only* in a pure resistive load. They should be ninety degrees out of phase with a pure inductive or pure capacitive load. And one-eighty out when you are actively sourcing rather than sinking current.

Anything from zero to three-sixty with a real world load. More on good old *Eli the Ice Man* is found back in MUSE100.PDF on *www.tinaja.com*

Say that you have a typical linear ac load driven from a clean sinewave. And you measure 100 volts and 3.0 amps with a pair of panel meters. The wattage could end up anything from *minus* 300 watts through zero to *plus* 300 watts.

There is simply no way to correctly measure ac power using an ordinary voltmeter and ammeter!

Do not even *think* of trying it!

assuming a clean sinewave– Whenever you are using parts of sinewaves (as in an ac power controller) or pulses, then *you **must** use some "true" rms current measurement* scheme.

Which is not trivial.

There's two main routes to handle wierd waveforms. Apply rectangular approximations or math calculus to analyze the rms to average ratio. Or you could use *Fourier Series* to deal with the waveform as a fundamental sinewave plus its significant odd and even harmonics. More on this in file MUSE90.PDF on *www.tinaja.com*

Measuring the current of a train of pulses using any analog panel meter will give us wildly wrong answers. Figure two shows us why your meter reading will be both way low and dead wrong. Every time.

Let's consider a train of repeating pulses. We should assume a one volt supply and a one ohm resistive load. A square wave will have a *duty cycle* of 1:1. The average current will be 0.5 amp and your average power will be 0.5 watt. The rms current will be the square root of the average power, or 0.707. Your rms current will equal 1.414 times the average current.

Next, consider a pulse with a 19:1 duty cycle. The average current will be 0.05 amp and the average power will be 0.05 watts. Your rms current will again be the square root of your average power, or 0.22361. This time, your rms current ends up a whopping 4.472 times the average current.

Which means that a typical meter current reading will measure low by a factor of *four* or so!

A *crest factor* (or the peak-to-rms ratio) is one measure of how extreme a waveform is. That 19:1 duty cycle pulse has a very high crest factor of 4.47. Just about all true rms current measurement schemes place definite limits upon how high a crest factor is permitted. Exceed their crest factor limit and your results will miss by a country mile.

ignoring waveform harmonics– Wierd waveshapes get their shape by having lots of higher harmonics. On any low duty cycle pulse, the lion's share of the energy lies in the harmonics and *not* in the fundamental.

Dozens and sometimes hundreds of harmonics could end up important. Your power company tends to get *very* upset when you draw harmonic energy instead of using fundamental energy. Such waveforms are now in fact illegal in Europe.

RMS Options

How can you measure RMS current or calculate real power? For typical measurements made most of the time, reading a voltmeter and an ammeter and multiplying the two together flat out will not hack it. Especially with bizarre waveforms, high harmonics, pulses, or when there are phase shifts between votage and current.

Or when you don't know the *exact* waveform you are looking at.

Most any dual meter measurement will just about always be dead wrong. One reason being that any traditional panel meter is an *average* measuring device. And that the product of some average most assuredly will *not* equal the average of the products.

Instead, you have to ask "what is the equivalent dc current you need to get the same quantity of consumed power?" As we have just seen, this equivalent dc current is also called the *rms* current.

Measuring true rms current never has and never will be easy. There is layer upon layer of subtlety.

Four popular rms measuring routes do include *heat matching*, the *graph method*, *multiply and average*, or by *using a math rule*…

the heat method– Make your current waveform heat a resistor. You take a second resistor that's under identical thermal conditions and then route an adjustable dc current to it. When the temperatures match, the rms currents will exactly match.

A *bolometer* is one example of a microwave method of measuring rms currents or power levels.

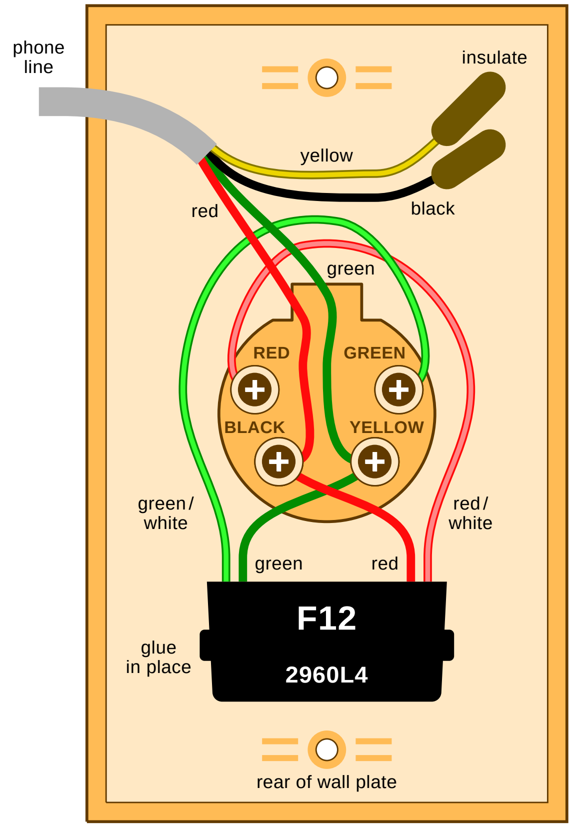


Fig. 3 – HOW TO INSTALL a 99 cent extension phone lockout.

the graph method– First, you'll obtain accurate waveforms of your voltage and current. You divide these up into very narrow increments. Increments so narrow that both the voltage and current remain nearly constant within each interval. You then multiply each interval's volts times its amps.

You then sum and average all the power from each interval to get the average power. You can next take the square root of your average power to find the rms current.

A digital oscilloscope can greatly simplify this method.

Whenever your load resistance is something different than one Ohm, you should take the square root of your average power divided by the load resistance. Again using Ohm's law. This is an example of *scaling*. More on normalization and scaling in my *Active Filter Cookbook*.

multiply-and-sum method– Take any fast analog or digital multiplier chip. Use this ic to continuously multiply volts times amps to get instantaneous power. Then sum and average to find your average power. Finally, take the square root of the average power to find the rms current.

Analog Devices is one source for analog multiplier chips optimized for rms current measurement. Start with their classic AD536A. Or else use the newer and lower power AD737.

Digital or analog, the numbers get out of hand for even moderately high crest factors. Thus, any commercial rms measurement scheme will *always* exactly spec the maximum allowable crest factor.

Fluke and *Tektronix* are two prime sources of true rms current measuring test instruments.

the rule method– Does what we just went through here. You integrate the square of a math definable waveform to find your average power. Take the square root of your average power (scaled, if needed, for resistance) to get your rms current. Then find the

SOME AEROGEL RESOURCES

Airglass AB PO Box 150 S-24500 Staffanstorp SWEDEN	**Harrick Scientific** PO Box 1288 Ossining NY 10562 (800) 248-3847	**Lockheed Aerospace** 3251 Hanover Street Palo Alto CA (415) 424-2171	**Ocellus Inc** 887-A Industrial Road San Carlos CA 94070 (415) 596-1408
Aspen Systems 184 Cedar Hill Street Marlborough MA 01752 (508) 481-5058	**Hubert van Hecke** Los Alamos Natl Labs Los Alamos NM 87545 (505) 667-5384	**Marketech International** 5869 Becon Street Pittsburgh PA 15217 (412) 421-3103	**Physical Review Letters** Box 900 Ridge NY 11961 (516) 591-4060
Audax of America 10 Upton Drive Wilmington MA 01887 (508) 658-0700	**Jnl of Non-Cryst Solids** Box 945 New York NY 10159 (212) 633-7300	**Matsushita Electric Works** 401 River Oaks Pkwy San Jose CA 95134 (408) 433-3386	**PolyStar** 6918 Sierra Court Dublin CA 94568 (510) 829-6250
Rob Biggar Cornell Low Temp Group Ithica New York 14853 (607) 255-7179	**Jozef Stefan Institute** Jamova 39 1000 Ljubljana, SLOVENIJA +386 61 177-3900	**NASA**/JPL Group 4800 Oak Grove Drive Pasadena CA 91109 (818) 354-4321	**Sandia National Labs** PO Box 5800 Albuquerque NM 87185 (505) 844-5678
Ray Cronise NASA Marshall Center Huntsville AL 35812 (205) 544-5493	**LAPP** Chemin de Bellevue, BP 110 74941 Annecy-le-Vieux CEDEX FRANCE	**NASA Tech Briefs** 41 E 42nd St #921 New York NY 10017 (212) 490-3999	**Science/AAAS** 1333 H St NW Washington DC 20005 (202) 326-6400
Dr. Le H. Dao INRS/Energie et materiaux Varennes Que J3X 1S2 (514) 929-8144	**Livermore Natl Lab** PO Box 808 Livermore CA 94550 (510) 422-1100	**Pamela M Norris** Univeristy of Virginia Engineering & App Sci Charlottesville VA 22903	**Super Conductor Mtrls** 128 Orange Ave Suffern NY 10901 (800) 932-9333

"correction factor" of the ratio of rms to average power.

An ordinary meter could then be used as a temporary stand-in to let you measure rms power. But is *only* accurate on the *exact* waveform you have just analyzed. And then *only* on a purely resistive load.

Note that your "correction factor" will *always* be considerably *higher* than 1.11. Watch this detail.

True rms calculations are easy and fun to do using the general purpose PostScript computer language. I've placed a FINDRMS.PS file to both the *Math Stuff* and the *PostScript* library shelves of *www.tinaja.com*. Along with a new FINDFOUR.PS that does a complete classic Fourier harmonic analysis of your chosen waveforms.

An Aside

Note that your average current is always waveform dependent! Figure two leads us to a rather curious and unexpected result. Assume you have a pair of dimmers or ac phase power controllers. Say you connect one to a 110 volt light bulb. And the second to a 32 volt light bulb. Then light them both to nearly full brightness. Your duty cycle will be rather high on the 110 volt bulb and extremely low on a 32 volt bulb.

I certainly would expect that rms current to be the same for both bulbs.

At identical power levels.

Among other reasons, because this is how rms current is *defined*. But, as figure two clearly reveals to us, your average current measures something like *three times* higher on a 110 volt light bulb! Every time.

Why? Because the average current is duty cycle dependent. And is thus an *utterly meaningless* measure of the circuit power or efficency.

FINDRMS.PS also can show us how average current measurement errors vary with triac phase angle for exact dimmer waveforms.

NEED HELP?

Phone or write all your US Tech Musings questions to:

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

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

99 Cent Telephone Extension Lockouts

Picking up your extension phone during a FAX transmission or some online connection can be bad news. As can having someone listen in on your private conversations.

An *extension lockout* is any device that goes between your line and your extension phone. These prevent the extension phone from working when the line is in use.

An open phone line is typically around 48 volts dc. Any in-use line drops to 9 volts dc or less. A beastie called a *bilateral switch* can be used to test the phone line. If there is high voltage on pickup, this switch turns on and allows phone use. If not, it stays off. The switch stays on so long as the extension phone is in use, then resets on zero current.

You can buy an extension lockout

NAMES AND NUMBERS

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

American Voice I/O Society
PO Box 20817
San Jose CA 95160
(408) 323-1783

Awards & Engraving
2800 Midway
Bloomfield CO 80020
(303) 469-0424

Butterworth-Heinemann
313 Washington St
Newton MA 02158
(617) 928-2500

ENM
5617 Northwest Highway
Chicago IL 60646
(773) 775-8400

Fluke
PO Box 9090
Everett WA 98206
(800) 443-5853

Microchip Technology
2355 W Chandler Blvd
Chandler AZ 85224
(602) 786-7200

Motorola
5005 E McDowell Rd
Phoenix AZ 85008
(800) 521-6274

National Semiconductor
2900 Semiconductor Rd
Santa Clara CA 95052
(800) 272-9959

Numeridex
241 Holbrook Drive
Wheeling IL 60090
(800) 323-7737

SS Manufacturing
135 Commerce Way
Walnut CA 91789
(909) 595-0450

Synergetics
Box 809
Thatcher AZ 85552
(520) 428-4073

Tektronix
PO Box 500
Beaverton OR 97077
(800) 835-9433

Vernier Software
8565 SW Beaverton-Hillsdale Hwy
Portland OR 97225
(503) 297-5317

for $11 or so. But I do believe I have a more flexible 99 cent solution you might like better.

On back in *Tech Musings* #96 we looked at a *Northern Telecom* 2960 network interface. I was pleasantly surprised to find out that *unmodified* units seem to work just fine for me as extension lockouts. At least on the electronic phones I have around here. These modules are easily hidden in a wall plate or built into custom gear.

Figure three shows the wall plate setup I use. This assumes you have a normal electronic phone that needs *only* the red and green wires. You first free and then *separately* tape or shrinkwrap both the black and yellow wires coming from the line. You then "borrow" the posts intended for black and yellow and use these to tie the incoming line to the module.

Make sure green goes to green and red to red. Solids go to your line and stripes go to your phone side. Only a screwdriver is needed for installation. Any old choice of glue or epoxy or a double stick tape can optionally hold the module to the wall plate.

Inline cord setups are also easily built. For temporary use.

A full schematic and more details on the 2960 appears in MUSE96.PDF I see no reason to expect any serious problems. Always place your module *immediately before* your extension phone, with the striped leads going to the phone end.

But if you do experience anything strange, try clipping one or both of the internal 150 ohm resistors. Or cut their foil traces. There's actually *two* lockouts inside your module, so you could conceivably control two lines at once by using some simple further mods. At 49 cents per line.

Cheap wall plates and related low cost phone accessories are available by way of *S.S. Manufacturing*. *Radio Shack* also stocks lots of this sort of stuff. The 2960 interface modules are available for 99 cents each from my *Synergetics Surplus*. Per the sidebar.

Aerogel Update

I finally got to hold an aerogel in my hot little hands. Amazing objects. Especially this one, which was one of the very first to ofter absolute crystal clear transparency.

An ordinary *gel* is a state of matter consisting of solid particles that have been suspended in some liquid. As in Jello. Or a gummy bear. An *aerogel* instead is a state of matter in which solid particles are suspended in a gas.

Sort of a "solid smoke".

Aerogels are often extremely light. Some are even *lighter* than air. They can be outstanding insulators (R50 in half of an inch!), blocking heat and sound. While freely passing light. A favorite photo shows a rose on one side of a thin aerogel which is being torched on its other surface.

Aerogels can be made by freeze drying silicon under pressure. Carbon aerogels are also possible, including edible ones made from seaweed.

Certain carbon aerogels do offer an amazing surface to volume ratio. One grape sized aerogel might posess the surface area of two football fields.

On the downside, Aerogels remain difficult, costly, and time consuming to manufacture. They are often very fragile. Yet some easily support 1500 times their own weight. Sadly, most silicon aerogels are water soluble.

Uses? Outstanding insulators of all types. Cerenkov radiation detectors. Micrometeroite capturing detectors. Cryogenic helium superfluidity. Sub atomic particle separators. Advanced battery research. Honeycombs. Ion beam milling. Neutron radioscopy. Refrigerators. Skylights.

High energy capacitors. Ultralight loudspeakers. Desalinization of sea water. Composite materials. Orbital debris collection. Superfluids. Metal oxide cataylsts. Thermal protectors. Microsphere filtration. Mesh getters. Exobiology instruments. Scintillator hodoscoping. Dielectric materials. Oxygen sensors. Water deionization. Sorbents. Calorimeters. Ferroelectric titantes. And bunches more.

Aerogels are now well beyond the curiosity stage and are producable in larger lab quantities. The production times have been cut from 25 hours on down to 30 minutes.

Mere mortals can access aerogels by asking the right questions in the correct place at the right time in the right manner. But high volume, low cost production processes are not yet available. And these do seem a tad tricky to make with a tire pump and some kitty litter at home.

I'll award a free *Incredible Secret Money Machine II* to the very first **Electronics Now** reader who sends me a homebrew aerogel.

My particular sample came from Ray Cronise from NASA. A pioneer among the supertransparency aerogel researchers. Clear aerogels are poised to revolutionize efficient windows or building skylights.

One place where aerogel stuff is likely to appear is in that *Journal of Non-Crystalline Solids*. A second is *Physical Review Letters*. Plus *Science* magazine.

And possibly *NASA Tech Briefs*.

The web is far and away your best way to explore aerogels. Just use my "search all sites" feature to reach *Alta Vista* or *Hotbot* and key on "aerogel". A superb bibliography on the silicon aerogels appears at *eande.lbl.gov/ECS/aerogels/sabib.htm*

I've also included the names and addresses for major aerogel players as this month's resource sidebar.

New Tech Lit

From *Motorola*, a *Technical and Applications Literature* guide. From *National*, their new *Opamp Databook* and a *Power IC's Databook*.

AVOIS is short for *American Voice I/O Society*. Who have seminars and a journal centering on human speech generation and recognition.

ENM offers a catalog of counting instruments and totalizers. Such as a $14 six digit LCD counter which runs off two flashlight cells.

Vernier Software has a catalog of their science education hardware and software. Includes physics, biology, and chemistry products.

That free *Professional's Guide to Bar Coding* from *Numeridex* does a fairly good job on fundamentals.

An unusual trade journal for this month is *A&E*. Short for *Awards and Engraving*. All sorts of oddball stuff here. Such as rubber stamp supplies, photopolymers, pad printing presses, laser tools, and diffusion inks.

A reminder that my classic *CMOS Cookbook* is back in print. Freshly printed by *Butterworth Heinemann*.

Autographed copies are available from my *Synergetics Press*. Per my nearby ad. Either by themselves or included in my bargain *Lancaster Classics Library* package.

You'll find further tech support on my *Guru's Lair* web site. Found at *www.tinaja.com* My recent additions include new library pages on Acrobat and wavelets. Plus files on caller id, VCR-plus codes, and flutterwumper utilities and tutorials.

As usual, most of the menitoned references do appear in our *Names & Numbers* or in the *Aerogel Resources* sidebars. Be sure to check these out before calling our tech helpline. ✥