Don Lancaster's

Tech Musings

June, 1998

Understanding crest factors
Temperature sensing circuits
Battery products trade journal
Great new SAW filter databook
Radiotron Designer's Handbook

In several previous columns, we have seen how excruciatingly hard it is to accurately measure ac power. Especially if phase shifts, reactive energy, nonlinearities, strange waveforms, sparking, strong harmonics, or low duty cycles are in any way involved.

More often than not, a casual or improper power measurement tends to end up wildly *low*, leading to dead wrong conclusions concerning real efficiency. Sometimes even leading to those "overunity" pseudoscience fantasies seen on the web.

Yet another power measurement gotcha involves…

Crest Factors

Figure one shows us a property of any repeating waveform known as its *Crest Factor*. We have already seen that the *peak* value of a waveform is its maximum height, your *average* value is like any other average, and that *effective* or *rms* value is your equivalent dc heating power. Because power involves either the *square* of current or voltage or else the *product* of these two, rms values are *always* equal or greater than average. Except for a pure dc current, rms is *always* greater than average.

Sometimes ridiculously so.

The crest factor of any current or voltage waveform can be defined as *the ratio of peak to rms*.

For instance, a dc voltage has a peak value of 1.0, an average value of 1.0, a rms value of 1.0 and thus a crest factor of 1.0. One cycle of a pure sinewave might offer a peak value of 1.00, an average value of 0.634, a rms value of 0.707, and a crest factor of 1.00/0.707 = 1.414.

A low brightness setting on a half wave lamp dimmer may give you a peak value of 1.28, a rms value of 0.32, an average value of 0.11, and a crest factor of 4.0. Values for that narrow impulse current waveform of a capacitance input diode rectifier will end up waveform dependent. But you can have a peak value of 1.414, an average value of 0.04, and a rms value of 0.22. For a 6.42 crest factor.

There's two key points here: First, *your ratio of rms to average current will change wildly from waveform to waveform!* This is *always* highly duty cycle dependent. Thus, most average responding meters lie like a rug when fed anything but whole cycles of pure ac sinewaves.

A figure of "1.11" rms-to-average seems to be widely bandied about. In reality, this figure is *not* a constant; its value can (and will) be *anything* from one to a million. In fact, nearly all real world waveforms will have rms to average readings far above unity. Leading you to wildly wrong underreporting on cheap meters.

Second, *every wattmeter design has its specific maximum allowable crest factor*. Crest factors above this critical value will usually read low, possibly severely so. Most ordinary wattmeters are totally unsuited to accurately measure lower duty cycle waveforms with high crest factors.

Always check on your crest factor limit to be sure.

Why is there a crest factor limit? Because the product of any two big numbers will end up as a very big number, meaning that a tremendous

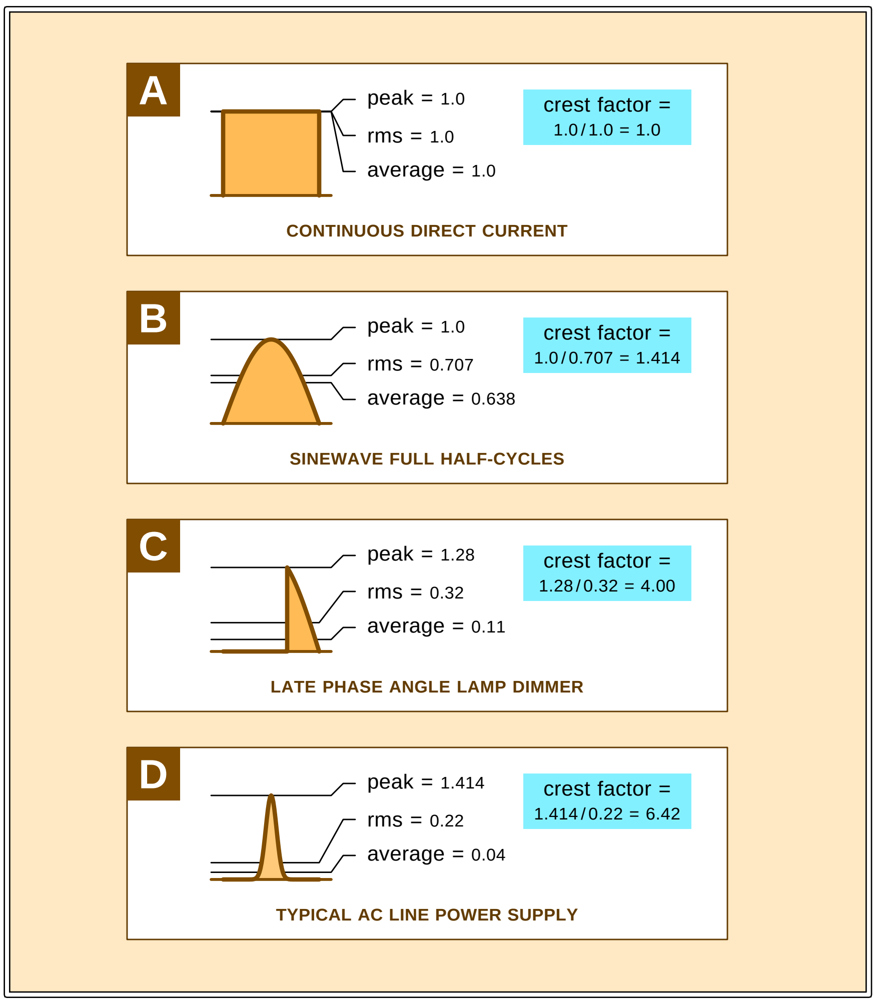

Fig. 1 – THE CREST FACTOR of any repetitive waveform is the ratio of its peak to rms values. Typical wattmeters will read uselessly low when their maximum allowable crest factor is exceeded.

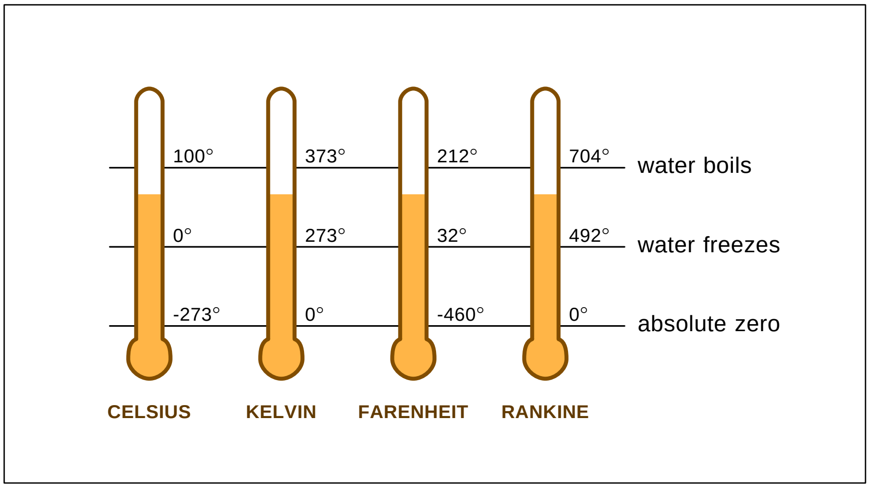

Fig. 2 – THE FOUR TEMPERATURE SCALES in common use.

dynamic range is required for large crest factors. Analog multipliers and rms chips often lack this extended range. High crest factors also imply higher frequencies and higher order harmonic waveform components as well. A workable scheme to handle high crest factors is to use a digital floating point multiply which can follow hundreds or more samples for each half cycle.

More details on accurate power measurement are in MUSE112.PDF, MUSE113,PDF, and MUSE123.PDF on my *www.tinaja.com*

Temperature Sensors

At long last, we're starting to get temperature chips which are cheap, accurate, linear, and really easy to use. We're also starting to see LCD digital thermometers selling for as little as $5 each from such sources as the *Innovative Solutions* folks.

So, I thought it might be a good time for a temperature measurement resources sidebar. But first, let us do a brief review:

Temperature is simply a measure of hotness or coolness of an object. More exactly, it is a measure of the atomic activity and motion.

That temperature point with zero activity is called *absolute zero*. As substances are heated, they typically move through solid, liquid, and gas phases as their atomic or molecular activity increases.

There are four popular temperature measurement *scales*. Each scale is broken down into lots of small and convenient *degree* units.

Details in figure two.

The metric *Celsius* or "Centigrade" scale is set to zero at water freezing and to one hundred at water boiling. Absolute zero is at -273 degrees C.

To do away with all the negative numbers for low temperatures or for such things as heat engine efficiency calculations which demand absolute values, the *Kelvin* scale gets used. In which absolute zero is zero, water freezing is 273 degrees, while water boiling is 373 degrees.

The *Farenheit* scale starts with zero at the coldest thing they knew how to make (a salt slurry) in a lab at the time, sets water freezing to 32 degrees and boiling at 212 degrees. Farenheit degrees are 5/9ths smaller than Centigrade degrees. Absolute zero is near -460 degrees F.

The absolute scale corresponding to Farenheit is known as the *Rankine* scale, with absolute zero being zero degrees and water freezing being set to 460 + 32 = 492 degrees R.

Some other terms: The *accuracy* of a temperature measuring device is how close its value will match your actual temperature. The *resolution* is the smallest temperature change that can be registered. The *linearity* is a plot of how the accuracy varies over a wide temperature range. The *range* is your spread between the max and min measurable temperatures.

The *time constant* is how long it takes to measure your temperature change to reasonable accuracy. The typical time constants of conduction devices are minutes in air, seconds in still liquids, and fractional seconds in moving liquids.

Some of the older ways to measure temperature include…

simple expansion– Most substances expand when heated. This effect can be greatly magnified when you place mercury or alcohol in to some tiny *capillary tube* to create a traditional thermometer. One quality supplier is *Brooklyn Thermometer*. *Abbeon Cal* is a second. A variation on this theme is to measure the pressure of gas in a fixed and closed container.

thermocouples– The *thermocouple* is made up from two dissimilar metals (sometimes copper and constantan) that have been welded together. The junction can generate a measurable voltage proportional to temperature. You have to either provide a second junction in an ice bath or whatever, or else build an *ice point reference* voltage to work against.

Typical thermocouples are rather expensive and klutzy, but do remain industry standards. They provide an

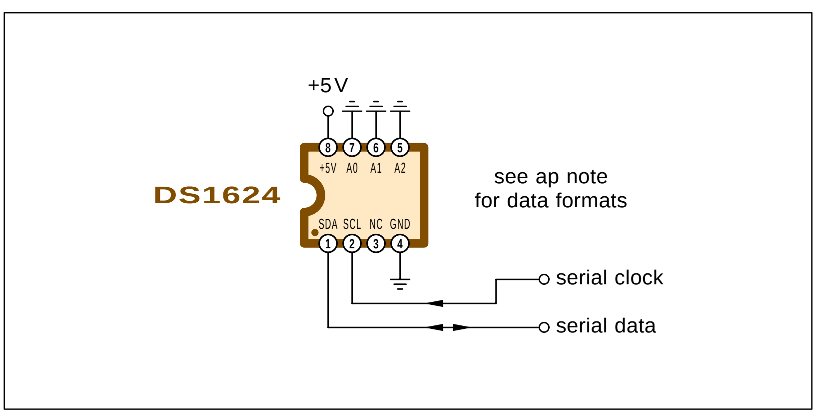

Fig. 3 – THE DALLAS DS1624 is a new self-sensing digital thermometer chip that offers 0.03 degree resolution and 13-bit data.

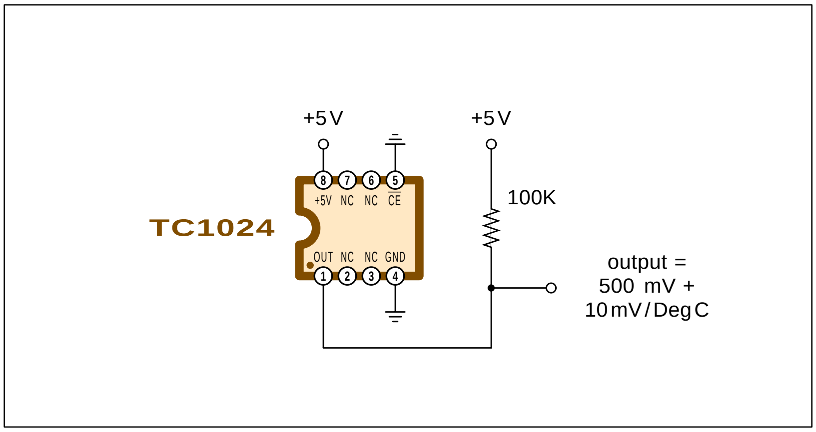

Fig. 4 – THE TELCOM TC1024 is an analog output temperature sensor.

exceptionally diverse measurement range. *Omega Engineering* has lots of info on thermocouples.

platinum rtd– The resistance values of most all materials are temperature dependent. When you have a *positive* temperature coefficient, resistance *increases* with temperature, and vice versa. Platinum wire is quite stable and suitable as a linear temperature sensor. Unfortunately, the resistance change with temperature is rather low, and fancy signal conditioning is needed. "rtd" stands for *Resistance Temperature Detector*.

thermistors– Metal oxide ceramics can be made up that have very strong negative temperature coefficients. Unfortunately, these are also highly nonlinear, leading to correction and conditioning hassles. *Yellow Springs Instruments* is one older supplier for corrected and repeatable temperature measuring thermistors. Thermistors with highly positive coefficients also make superb circuit protectors and self resetting breakers. *Raychem* is one of the major sources.

optical pyrometers– Take a wire and heat it with an adjustable current. As the current increases, the wire will go through red, orange, and finally its white stages. By matching the wire color to the background color, your background temperature might be measured. This is useful for remote measurement of rather hot objects, such as steel billets in a rolling mill.

emissivity– When objects are heated, they will generate electromagnetic radiation in the infrared region. Often following a characteristic broadband *black body radiator* curve. Numerous infrared energy sensing devices exist. These see use for everything from night vision and intrusion detectors to fire service "hot spot" detectors. One source for low cost sensors is *Amp Piezo*. A useful trade journal is *Advanced Imaging*.

quartz crystals– Quartz crystals can be specially cut so they have a linear temperature response. By placing one crystal in a fixed oven and comparing its frequency against one in a space being measured, extreme temperature accuracy can result. To a thousandth of a degree or finer. *Hewlett Packard* is one source of suitable instruments. Needless to say, there are plenty of gotchas when measuring ultra small temperature differentals.

plain old diodes– A silicon diode has a temp coefficient of ten millivolts per degree C or so. And thus makes a low cost and simple temp detector. Calibration and conditioning will be required, because the temperature change tracks on top of a device-dependent 0.6 volt offset. The *Radio Shack* 277-0123 is a typical diode sensed LCD temperature panel meter.

differential currents– Junctions in bipolar transistors are diodes. By measuring a pair of junctions in a fixed ratio of currents, a linear temp output can result. By adjusting the exact current ratio, the degrees per millivolt of output can easily be adjusted. The classic chips here are the *National* LM34 (Farenheit) and LM35 (Centigrade). But the general idea is the basis of most of today's new sensor semiconductors

The New Temp Chips

There's bunches of new low cost temperature measuring ic's that are accurate, have high resolution, and need little or no calibration. While *Dallas Semiconductor* seems to be leading the pack, an industry wide sampling might include…

Analog Devices TMP03– We did look at this chip back in MUSE114.PDF. Your output is a rectangular wave whose duty cycle should be temp dependent and whose frequency can range from 20 to 50 Hertz. Half a degree accuracy over a wide range. The linear temperature output is easy to read digitally. A simple resistor and capacitor can be used to get an equivalent analog output as well. No calibration is required.

This chip would seem particularly well suited for wireless remote apps.

Dallas DS1624– Measures its own internal temp to 13-bit resolution and a 0.03 degree accuracy. Outputs serial digital temperature info as well as providing for nonvolatile storage of precise calibration values. -55C to +125C operating range. A schematic appears in figure two. One variation on this is their DS1820 "temperature in a can" chip. This one powers and communicates over a single wire. It also offers thermostat limit values.

See their ap note #105. Note that the address inputs can input binary values, letting you connect up to eight sensors on a single data and clock line pair.

National LM75 Widely used chip gives you nine bit resolution to give half a degree C temp measurement from -55C to+125C. Serial digital comm. Both temp measurements and thermostat settings are provided for. Nominal accuracy is two degrees. Dallas has just released their low cost DS-75 upgrade for this part which provides up to twelve bit and 0.06 degree resolution.

Maxim MAX1617– A precise digital thermometer which reports its own temperature as well as that of any remote diode or pn-junction sensor. Intended to keep tabs on Pentium and other fancier CPU device internal temperatures. But also serves obvious indoor/outdoor apps. Uses standard

SOME TEMPERATURE SENSOR RESOURCES

Abbeon-Cal
123-208A Gray Ave
Santa Barbara CA 93101
(805) 966-0810

Advanced Imaging
445 Broad Hollow Rd #21
Melville NY 11747
(516) 845-2700

Amp Kynar Piezo
PO Box 799
Valley Forge PA19482
(610) 650-1500

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

Brooklyn Thermometer
90 Verdi St
Farmingdale NY 11735
(516) 694-7610

Dallas Semiconductor
4401 Beltwood Pkwy S
Dallas TX 75244
(214) 450-0400

Electronic Comp News
1 Chilton Way
Radnor PA 19089
(215) 964-4345

Electronic Products
645 Stewart Ave
Garden City NY 11530
(516) 227-1300

Electronics Test
1 Penn Plz
New York NY 10119
(212) 714-1300

Hewlett-Packard
PO Box 10301
Palo Alto CA 94303
(415) 857-1501

Innovative Solutions
PO Box 7676
S Lake Tahoe CA 96150
(800) 542-1844

Maxim
120 San Gabriel Dr
Sunnyvale CA 94086
(800) 998-8800

Measurement & Control
2994 W Liberty Ave
Pittsburgh PA 15216
(412) 343-9666

Medical Electronic Prds
2994 W Liberty Ave
Pittsburgh PA 15216
(412) 343-9666

Medical Equip Designer
29100 Aurora Rd #200
Solon OH 44139
(216) 248-1125

NASA Tech Briefs
41 E 42nd St #921
New York NY 10017
(212) 490-3999

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

Omega Engineering
One Omega Dr
Stamford CT 06907
(800) 826-6342

Raychem
300 Constitution Drive
Menlo Park CA 94025
(800) 227-7040

Sensors
174 Concord St
Peterborough NH 03458
(603) 924-9631

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

TelCom Semiconductor
1300 Terra Bella Avenue
Mountain View CA 94043
(415) 968-9241

Temic
2201 Laurelwood Rd
Santa Clara CA 95056
(408) 970-5700

Yellow Springs Insts
Box 279
Yellow Springs OH 45387
(513) 767-7241

microcontroller serial comm.

Free samples are available.

Telcon TC1024– This one is an older temperature to voltage converter ic, working over a -40C to +125C range. A 2.0 degree accuracy and 0.8 degree linearity is offered. Output voltage is ten millivolts per degree C. Single supply voltage can range from 2.2 to 12 volts. The operating current is typically 40 microamperes active and 5 microamps in shutdown mode. A schematic is shown in figure four.

There is an 0.5 volt offset in the output. A companion TC1073 device offers zero offset, but requires use of a negative supply. Negative temps output with negative voltage.

Other temperature sensing chips can be found at *www.questlink.com* Especially all the newest and latest devices. Your best two trade journals here are *Sensors* and *Measurement & Control*. Several others are listed in the nearby sidebar.

Radiotron Designer's Handbook

What is the greatest electronics book of all time? A recent candidate would be *The Art of Electronics*. But it is no contest that the *Radiotron Designer's Handbook* has to be the all time clear cut winner. This fat book from long ago and far away has way more than you could possibly ever want to know about vacuum tube electronics.

There's been a lively trade on the web to scrounge collectible copies. Some of which sell for outrageous prices. Try *www.dejanews.com* for current activity.

But the big news is that the entire *Radiotron Designer's Handbook* is newly available on CD ROM from *Audio Amateur Publications* at $65.

New Tech Lit

From *R.F. Monolithics*, a new data book on their SAW filters and low power rf transmitters and receivers.

NEED HELP?

Phone or write all your US Tech Musings questions to:

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

From *Gennum*, a data book on unusual video integrated circuits, for both digital and analog uses.

Analog Devices has a stunning new ADV601LC wavelet compression chip for *real time* digital video. The cost is $15 in quantity.

A review on thermoluminescence is found in *Science* for February 17th of 1998. See pages 1322 and 1323. Sonoluminescence is the blue light emitted from tiny bubbles formed by cavitation. For largely yet unknown reasons, the bubbles can approach temperatures of 50,000 degrees and incredible pressures. Yet are easily played with on a kitchen table.

New trade journals for this month include *Battery Power Products and Technology* and *NC Shop Owner*. The latter is on numerically controlled machine tools, laser cutters, rapid prototyping, and such.

Lindsay Press now has a new/old *Manual of Vacuum Practice* book they've just added to their already stocked *Do It Yourself Vacuum* and *Introduction to Vacuum Technology* titles. Two other useful resources for amateur vacuum technology include Steve Hanson's *Bell Jar* and Shawn Carlson's unique *Society of Amateur Scientists* group.

NAMES AND NUMBERS

Adobe Acrobat System
1585 Charleston Rd
Mountain View CA 94039
(800) 833-6687

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

Audio Amateur
Box 576
Peterborough NH 03458
(603) 924-9464

Battery Power Prds
10555 E Dartmouth #330
Aurora CO 80014
(303) 745-5711

Bell Jar
35 Windsor Dr
Amherst NH 03031
(603) 429-0948

Burr-Brown
6730 S Tucson Blvd
Tucson AZ 85706
(520) 746-1111

Gennum
PO Box 489, Station A
Burlington ONT L7R3Y3
(800) 263-9353

Libby Owens Ford
PO Box 799
Toledo OH 43697
(419) 247-4724

Lindsay Publications
PO Box 538
Bradley IL 60915
(815) 935-5353

NC Shop Owner
1100 Superior Ave
Cleveland OH 44114
(216) 696-7000

RF Monolithics
4441 Sigma Rd
Dallas TX 75244
(972) 448-3700

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

Soc Am Scientists
1549 El Prado
San Diego CA 92101
(800) 873-8767

Solutions Software
1795 Turtle Hill Rd
Enterprise FL 32725
(407) 321-7912

Other new book titles include the "gotta have" *Troubleshooting Analog Circuits* from Bob Pease and Mark Swank's *Designing & Implementing Microsoft Index Server*. *Adobe* now has a free PDF plugin for this search engine, meaning that you can now do simultaneous full text searches with both Acrobat and HTML. More on PDF and Acrobat can be found at *http://www.tinaja.com/acrob01.html*.

Access to these and other great technical books might be found at my *http://www.tinaja.com/amlink01.html*

The complete set of all 50 federal CFR regulations is now available on two CD ROM disks for $63 through *Solutions Software*. Included are the complete FCC part 47 rules.

Free samples this month include the DCP01 isolated dc power supply from *Burr-Brown*, and an AD158X precision voltage reference you can get from *Analog Devices*.

From *Libby Owens Ford*, details about their conductive *TEC-Glass* products. These are fairly transparent conductive glass sheets intended for such practical apps as supermarket non-fogging beer cooler doors.

Tutorials and links to hydrogen resources can be newly located at *http://www.tinaja.com/h2gas01.html* Other new site additions include lots of fresh content on wavelets, wind energy, Santa Claus machines and home automation. Plus my new fast nav site map and master directory at *http://www.tinaja.com/map01.html*

For the fundamentals of starting up your own technical venture, get a copy of my *Incredible Secret Money Machine II*. Details are in my nearby *Synergetics* ad. Or download my full interactive online catalog found at *http://www.tinaja.com/synlib01.html*.

My new *InfoPack* "cash and carry" consulting service is now going great guns. You can get instant answers to most any reasonable tech question or resource problem. Full details are at *www.tinaja.com/info01.html*

As usual, most of the mentioned items should appear in our *Names & Numbers* or the *Temperature Sensors* sidebars. Be certain to check here before you call our US technical helpline. Let's hear from you. ✥