Don Lancaster's

Tech Musings

June, 1996

Using Delta-Wye transforms
Professional audio resources
Acrobat Amber beta software
Building your own Tesla coil
Three phase magic sinewaves

One of our recent *tinaja quest* winners was D.C. Cox from *Resonance Research*. This firm is the leading supplier for the bigger Tesla coils and Van De Graff generators you find in science centers, museums, and planetariums.

He is also newly offering his free do-it-yourself reprint on building up your own smaller Tesla machine.

Thoughts on Tesla Coils

A Tesla coil is nothing but a huge resonant transformer. One intended to make high voltage, high frequency electricity. Otherwise known as "lots of sparks". Sparks which literally can stand your hair on end. Or light up an unconnected fluorescent tube you are holding in your hand.

The key secret to Tesla coil design is a quite high Q air core transformer having precisely the right amount of input source coupling. The resonance buildup does a "Q-multiplier" effect to generate the high voltage.

The ultra high voltages are usually safe because they are high frequency alternating current. That *skin effect* tells us that ac currents travel only on the *outside* of conductors. The higher the frequency, the less will be your skin effect depth. The output from a Tesla coil can often be routed along a person (or a chain of people) without significant shock hazards.

Amazingly, most of the Resonance Research machines still use a spark gap for their input switching. Above a certain power level, spark gaps still do have compelling advantages over tubes or solid state devices.

Needless to say, a Tesla coil is one really horrendous generator of radio frequency interference. These can be a most blatant violator of FCC Part 15 regs. *All Tesla coils are illegal.*

There are several persistent *urban lore* type myths that Tesla coils are in some manner a "suppressed" or "lost" source of "free energy".

The original myth can be traced to one of two sources: Either his really bad misunderstanding of differences between resonance stored energy and source converted energy.

Or as something between too much hype and an outright scam involved in seeking lab funding.

Do careful and objective research and you will discover *there is not one shred of either actual or theoretical evidence that this sort of hogwash is even remotely possible.*

Tesla coils are closely related to color tv flyback transformers and to all the UHV ultra high voltage power line transmission research. In spite of countless hours of formal research in these fields, not the least hint of any over unity energy has emerged.

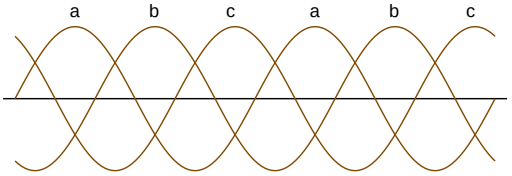
Another good source for hands-on Tesla stuff is *Lindsay Publications*. The *Tesla Bookstore* is another useful resource. But you'll be way better off limiting your readings to those books and the reprints *by* Tesla, rather than errant ramblings *about* him.

If you really want to get into all of the free energy Tesla hogwash, check *High Energy Enterprises*, or else that *International Association for New Science*, that *International Guild of Advanced Science*, or *Borderlands*.

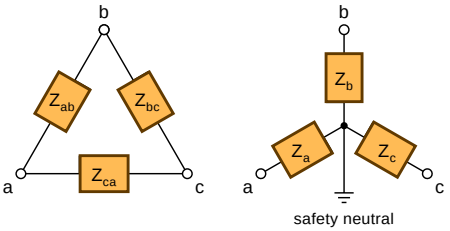
Check out that *KeelyNet BBS* for a mesmerizingly outrageous source for late-breaking pseudoscience info.

And, of course, for a back-to-earth reality check, be certain to read the

Three phase power consists of a triad of voltages spread by 120 electrical degrees. Advantages for higher energy users include a constant and a more efficient power flow, lower vibration machinery that starts and reverses easily, and rectifiers that are more economically filtered…



Two methods of connecting loads to a three phase system are the Delta and the Wye. Each has advantages and limitations. Note that currents in a Delta load are higher for a given input voltage…



For any Delta load, there is an equivalent set of Wye impedances, and vice versa. Here are the classic Delta-Wye transform pairs…

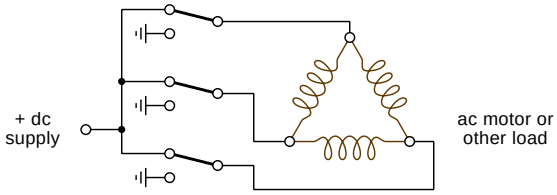
$$Z_{ab} = \frac{Z_aZ_b + Z_bZ_c + Z_cZ_a}{Z_c} \qquad Z_a = \frac{Z_{ab}Z_{ca}}{Z_aZ_b + Z_bZ_c + Z_cZ_a}$$

$$Z_{bc} = \frac{Z_aZ_b + Z_bZ_c + Z_cZ_a}{Z_a} \qquad Z_b = \frac{Z_{ab}Z_{bc}}{Z_aZ_b + Z_bZ_c + Z_cZ_a}$$

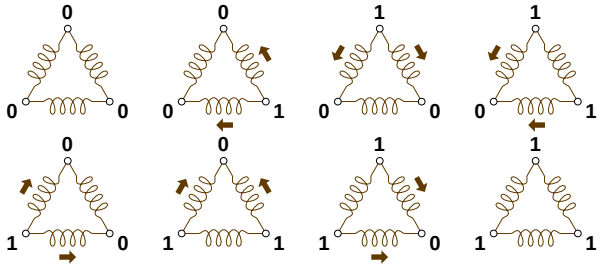
$$Z_{ca} = \frac{Z_aZ_b + Z_bZ_c + Z_cZ_a}{Z_b} \qquad Z_c = \frac{Z_{bc}Z_{ca}}{Z_aZ_b + Z_bZ_c + Z_cZ_a}$$

Fig. 1 – SOME FUNDAMENTALS of three phase power.

A three phase delta load is normally driven by three "half bridge" drivers. These usually require a total of six power switching devices…



When using digitally switched unipolar inputs, there are only eight possible bipolar motor winding current results…



Just as there are delta-wye transforms, we can list these eight pairs of unipolar delta input to bipolar motor coil forward and reverse transforms…

0 0 0	0 0 0
0 0 1	0 - +
0 1 0	- + 0
0 1 1	- 0 +
1 0 0	+ 0 -
1 0 1	+ - 0
1 1 0	0 + -
1 1 1	0 0 0

+ 0 -	1 0 0
+ - 0	1 0 1
0 + -	1 1 0
0 - +	0 0 1
- + 0	0 1 0
- 0 +	0 1 1
0 0 0	0 0 0
0 0 0	1 1 1

Further analysis easily proves that *any* motor winding magic sinewave bit sequence which has a zero third harmonic will end up fully delta friendly.

Fig. 2 – THREE PHASE "DELTA FRIENDLY" magic sinewaves require only simple input switches. Yet they produce positive, negative, or zero winding currents. Provided you use carefully chosen sequential commands.

Skeptical Inquirer instead.

I've been thinking about gathering all my pseudoscience info into a new book. Give me a call if you have any interest in this.

Watch that Q!

A recent caller had a brilliant but flawed idea on how to simplify his Tesla coil. He wanted to use a *Slinky* for his main coil. Eliminating most of those messy winding hassles.

The only tiny oint in the flyment is that Tesla coils *must* be high Q and nearly lossless. A steel Slinky won't hack it. But a gold plated one or a beryllium copper version may work.

In another time, long ago and far away, this student came to me hours before his Theremin project was due for a course final show-and-tell. The bright silver colored coils sure were pretty. It seems that the story he was copying clearly said to use #30 wire in his oscillator coils. While he found lots of #28 and #34 copper wire, the only #30 he could find seemed to be made from Nichrome.

Three Phase Power Basics

Most of your utility electricity gets generated as three phase power. And pretty near all larger industrial and ag motors are three phase.

Ever wonder why?

Figure one shows us a three phase waveform. Three windings get spaced out 120 degrees around a generator's stator. Thus producing three identical sinewave waveforms whose electrical phase is also 120 degrees.

Your first great advantage of three phase is that all *three phase power is continuous*. Go through the math, and you'll find that the instantaneous sum of the power on all three phases will always add to the same value.

In a single phase system, there are times when very little power is being delivered to you. Other times, much more than average is delivered. Thus, three phase power is more efficient and has lower line losses.

Three phase motors also start a lot easier than single phase ones. Most of them are easily reversed, simply by swapping phases. Because of the continuous power, most vibration and noise can end up a lot lower.

Three phase power sources can be easily rectified for dc. Your ripple is much lower and the ripple frequency is way higher. Which is one of many reasons that a car alternator is a three phase ac generator.

It turns out there are two standard ways of connecting a transformer or motor or whatever to any three phase power line. With a *delta* connection, one winding goes between phases *a* and *b*. A second goes between phases *b* and *c*. And the last one routes from phases *c* and *a*.

In the *wye* connection, one end of each motor winding gets connected together. And usually brought out to a fourth line called a *safety neutral*. The free end of each winding will get connected to phase *a*, *b*, or *c*.

Under balanced loading, you have a safety neutral current of *zero*. Even with some major unbalance, the safety neutral current still stays low.

Delta and wye both feature unique advantages and disadvantages. Both do see a lot of use. Note that voltages are 1.732 times higher in wyes and the currents are 1.732 times higher in deltas. With 1.732 being the square root of three.

Thus, you could easily overload or underpower any load by making your incorrect choice of delta or wye. But that's what power engineering is all about in the first place.

It is simple to show that any delta has a wye equivalent. And vice versa.

This is called a *delta-wye transform* or else a *wye-delta transform*. I have also shown these in figure one.

Your major disadvantage of three phase power is that three times the wiring is needed, combined with far more expensive switches.

Plus, you need three times as many transformers. Thus, single phase gets used for home, shop, and other "low power" uses. While the advantages of three phase power are reserved for the industrial and ag users.

Much more on three phase in any college power textbook. Such as my utterly ancient favorites of Skilling's *Electrical Engineering Circuits* or Fitzgerald and Kingsley's *Electrical Machinery*.

Three Phase Magic Sinewaves

As all you regular readers already know, I have been doing bunches of unique new *magic sinewave* research. Magic sinewaves are rather carefully chosen and ultra long sequences of repeating ones and zeros. Sinewaves of precisely controlled amplitude and amazingly low distortion.

Compared to classic PWM, these brand new magic sinewaves can offer elegant simplicity along with superb efficiency. For such diverse apps as induction motor speed controls, solar panel inverters, electric auto drives, power factor correctors, home energy efficiency improvers, or for reliable uninterruptible power supplies.

A participant at one of our magic sinewave seminars did ask me a very embarassing question, though. A real scary back-to-the-drawing-board one: "How can magic sinewaves get used with three phase loads that use only *three* half bridge drivers?"

The original magic sinewaves used individual "H-bridge" drivers. These needed access to *both* ends of *each* winding phase. For the three winding currents of (+), (0), or (-).

All of which is just fine for single and two-phase users. But in the real world of big time three phase power, we rarely have access to both ends of each winding. Especially doing some upgrade or retrofit. And we'd sure like to get by using a mere *six* active power devices. Instead of the twelve the full H-bridge route needs.

Well, for openers, the length of our magic sinewave sequence should be a multiple of three. Such that our three phases happen on bit boundaries. For simplicity and compact files, we'd also want a multiple of four. For that way, we'll need only work with and store one of four *quadrants*.

Next for something a tad subtle: Another factor of eight sure would be handy. This lets each one of the three sinewaves work out of the same *bit position* of each 8-bit stored quadrant sequence. And, last time I checked, 3 x 4 x 8 = 96.

Thus, to be three phase friendly, *a magic sinewave's length should be a multiple of 96 bits*. And several *very* interesting libraries of 384- and 768-bit magic sinewaves already exist.

```
1000000100100010101100110110111011111011111101111
    Hexadecimal:       $8122B36EF7EF
Fundamental Amplitude: 0.866208
    Transitions:       22
    Filter:            secondorder2.0
Distortion 3-17:       0.0739%.
Relative Harmonics 3 through 17:
    0.0          -0.000591363   -0.000042485   0.0
   -0.000167379   0.000352492    0.0          -0.000206194


001000000011000101010011101100111111010111111011
    Hexadecimal:       $203153B3EDFB
Fundamental Amplitude: 0.814612
    Transitions:       21
    Filter:            secondorder2.0
Distortion 3-17:       0.0445%.
Relative Harmonics 3 through 17:
    0.0           0.000155364   0.000052628   0.0
    0.000139262  -0.000382276   0.0           0.000077191


001000000010011000011010110100111110101101111110
    Hexadecimal:       $20261AD3EB7E
Fundamental Amplitude: 0.751198
    Transitions:       22
    Filter:            secondorder2.0
Distortion 3-17:       0.0641%.
Relative Harmonics 3 through 17:
    0.0          -0.000198935  -0.000186813   0.0
   -0.000492521   0.000138928   0.0          -0.000273419
```

Fig. 3 – OF THE 281,474,976,710,656 possible 192-bit quadrant symmetric magic sinewaves, a scant 43,046,721 end up three-phase "delta friendly". Here are three of the more interesting examples.

```
; Code module to provide a time delay of n instruction
; cycles. n can vary from 4 to 255 and is destructively
; read from COUNTER. There are 8 or 9 overhead cycles.

; The module is easily extended to 9 or 10 bits.

DELAY     BCF S,C           ; clear carry (if needed)
          RRF COUNTER,1     ; bit 0 into carry
          BTFSC S,C         ; stall one cycle?
          GOTO EQ1          ;  yes, one extra cycle
EQ1       BCF S,C           ; must clear carry
          RRF COUNTER,1     ; bit 1 into carry
          BTFSS S,C         ; stall two cycles?
          GOTO LOOP         ;  no, no extra cycles
          GOTO EQ2          ;  yes, two extra cycles
EQ2       NOP               ;

LOOP      BCF S,C           ; 4*n cycle delay loop
          DECFSZ COUNTER    ; round and round
          GOTO LOOP         ; till done
```

Fig. 4 – CORRECTED VERSION of the PIC time delay generator.

PROFESSIONAL AUDIO RESOURCES

B&H Pro Audio
119 W 17th Street
New York NY 10011
(800) 947-1182

Dale Pro Audio
7 East 20th Street
New York NY 10003
(212) 475-1124

Denon
222 New Road
Parsippany NJ 07054
(201) 575-7810

High End
Box 357
Sea Cliff NY 11579
(516) 676-2830

High Performance Review
Box 346
Woodbury CT 06798
(203) 266-0084

Home & Studio Recording
21601 Devonshire St #212
Chatsworth CA 91311
(818) 407-0744

Journal AES
60 E 42nd St Rm 2520
New York City NY 10165
(212) 661-2355

Journal ASA
335 E 45th St
New York City NY 10017
(212) 661-9404

MIX Bookshelf
6400 Hollis St #12
Emeryville CA 94608
(800) 233-9604

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

Pro Audio Review
5827 Columbia Pike 3rd Fl
Falls Church VA 22041
(703) 998-7600

Pro Sound News
2 Park Avenue 18th Fl
New York NY 10016
(212) 213-3444

Radio World
5827 Columbia Pk #310
Falls Church VA 22041
(703) 998-7600

Roland Digital
7200 Dominion Cir
Los Angeles CA 90040
(213) 685-5141

SMPTE
595 W Hartsdale Ave
White Plains NY 10607
(914) 761-1100

Studio Sound/BE
245 Blackfriars Road
London SE1 9UR, ENGLAND
(071) 620-3636

What do we have to do beyond this to also become what I will call being *delta friendly*?

The delta friendly sinewave needs only three leads. And each of those leads need only get connected to a positive supply or ground. Figure two should get us started.

With simple SPDT or "half bridge" drivers on each line, there are only *eight* possibilities here. Namely, the binary combinations of 000, 001, 010, 011, 100, 101, 110, and 111. We might define a "clockwise" winding current as (+) and "counterclockwise" as (-).

We immediately see that the eight combinations can give us our choice of (+), (0), or (-) currents.

Now for the tricky part: *For all of your possible input combinations, the winding currents always must sum to zero!* You could have zero current on all three windings (cases 000 or 111). Or have zero current on one winding, positive current on one, and negative current on one (as in cases 001, 010, 011, 100, 101, and 110).

Next, think about this really hairy concept: Not only do winding states *a*, *b*, and *c* have to occur together, but state *b* will occur *in* data stream *a* at *one third* of the way through the time sequence, and state *c* also happens *in* data stream *a* at *two thirds* of the way through the time sequence!

We already do know that our three states must sum to zero. But this also newly tells us that the three states are bits that are separated by one-third of their cycle distance in each sinewave sequence. Thus, the one-third spaced bits must *also* sum to zero.

Which tells us that *a delta friendly magic sinewave must have a forced zero third harmonic!*

And that is all there is to it. To be both three phase friendly and delta friendly, just *select 96-bit multiple magic sinewaves that have their third harmonic forced to zero*.

Most power books also tell us that there can be no third harmonic line current on any delta connected three phase load. Sort of an independent check on what we've discovered.

Several examples of 192 bit delta friendly magic sinewaves are shown in figure three.

You will find vastly more magic sinewaves than there are particles in the galaxy. Untold zillions versus a mere 10^70. So finding the good ones gets real tricky. Indeed, there are lots and lots of highly useful and delta friendly magic sinewaves. But magic sinewaves that are *not* delta friendly might perform better.

Just as there are delta-to-wye and wye-to-delta transforms, there's also simple math which gets you from the *"positive-ground-negative"* winding currents to the *"positive-ground"* line currents. I've also shown these back in figure two.

When you want zero current on all three windings at once, you'll have your choice of using 000 or 111 input states. At first glance, either would work just fine. But it turns out one or the other might be more efficient and needs fewer transitions.

Ferinstance, if your *previous* state was 000 and your *next* state was 010, use of a 000 would require only *one* transition. But use of 111 would need *five* transitions instead.

Obviously, you pick the one with the fewest transitions. Because fewer switchings certainly means less high frequency losses. And usually means higher efficiency. Sometimes a 000 is clearly better. Other times, 111 is the only way to go. Other times (such as a previous 010 and a following 101), it doesn't matter at all.

The bottom line: Magic sinewaves work just fine with half bridge delta drives. So long as you use only those which include (A) a forced zero third harmonic, and (B) bit lengths that are an integer multiple of 96.

As you may have guessed, this is a billion dollar new opportunity that is very much up for grabs. I'll be happy to send you a free tutorial on magic sinewaves when you call or write.

You can also ask me for a formal proposal that explains in detail our seminars, PIC sourcecode, and the

NEED HELP?

Phone or write all your US Tech Musings questions to:

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Web page: *www.tinaja.com*

NAMES AND NUMBERS

Borderland Research
PO Box 429
Gaberville CA 95542
(707) 986-7211

Coriolis Books
7339 E Acoma Dr Ste 7
Scottsdale AZ 85260
(602) 483-0192

Scott Edwards Electronics
964 Cactus Wren Lane
Sierra Vista AZ 85635
(520) 459-4802

Gale Research
835 Penobscot Blvd
Detroit MI 48226
(313) 961-2242

High Energy Enterprises
PO Box 5636
Security CO 80931
(719) 475-0918

Intl Guild Advanced Sciences
255 N El Cielo Rd #565
Palm Springs CA 92262
(619) 327-7355

Intl Assn New Science
1304 S College Ave
Fort Collins CO 80524
(303) 482-3731

Johnson Smith
PO Box 25500
Bradenton FL 34106
(941) 747-2356

KeelyNet BBS
Box 1031
Mesquite TX 75149
(214) 324-3501 BBS

Lin-Wood Products
506 Oakland Avenue SW
Grand Rapids MI 49503
(800) 458-1578

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

Loose Ends
PO Box 20310
Salem OR 97307
(503) 390-7457

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

Parallax
3805 Atherton Rd #102
Rocklin CA 95765
(916) 624-8333

Resonance Research
E11870 Shadylane Rd
Baraboo WI 53913
(608) 356-3647

Skeptical Inquirer
PO Box 703
Buffalo NY 14226
(716) 636-1425

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

Tesla Book Store
Box 121873
Chula Vista CA 91912
(805) 646-3371

new partners programs.

Both reprint and proposal are also available at *www.tinaja.com*

Time Delay Correction

Uh, the neat PIC time delay utility I showed you a few columns back had one bug in it. A PIC spends *one* cycle if a skip is *not* taken, and *two* cycles if an instruction skip *is* taken.

The corrected version is shown in figure four. Sorry about that.

Professional Audio Resources

I have just picked up a free new subscription to *Pro Audio Review*. A trade journal that more or less reports what its name implies.

It has detailed reviews of high end amplifiers, mixers, and microphones. For tv, video, CD, and radio.

For this month's resource sidebar, I've tried to gather together some of the other pro audio resources.

A second major magazine is *Mix*, who also operate an outstanding *Mix Bookshelf*. Where you will find just about any book on audio.

The leading technical organization is the *Audio Engineering Society*.

The finest audio pub in the world seems to be that British *Studio Sound and Broadcast Engineering*.

Let me know if I've missed any of your favorites here. A free *Incredible Secret Money Machine II* if you tell me about any pro audio resource I don't already know about.

New Tech Lit

A real fine new collection of PIC related data books is now offered by *Microchip Technology*. These include the *PIC 16/17 Microcontroller Data Book*; their *PIC 16C8X Data Book*; *PIC 14000 Data Book*; a *PIC 16C7x*

Data Book; their *PIC 16C62X Data Book*; *ECHV Update I*; the *MPASM Assembler Guide*; *Third Party Guide 1996*; their *Non-Volatile Memory Products Data*; *Embedded Controller Handbook*; *Serial EPROM Tutorial Series I-III*; the *Development Systems Ordering Guide*; *BBS System User's Guide; MPSIM Users Guide*; and the *HCS300 Data Book*.

Their PIC, of course, is *the* finest microcontroller. Nothing else comes remotely close. Other PIC resources include *Scott Edwards Electronics*, and the superb *Basic Stamp* products offered by *Parallax*.

A unique collection of PC-related books is offered by *Coriolis Books*.

A new *CD Roms in Print 1996* is freshly offered by *Gale Research*. It reviews over 9000 titles.

Free copies of *Acrobat Reader 3.1* are downloadable at *www.adobe.com* This wonderment lets you view full technical reprints on line. Part of it plugs into *Netscape Gold*. Which you can find at *netscape.com*

I often like to check out the hobby and craft catalogs. These can be a great source for products and ideas. One example is the *Source Place for Creative Living* "owner's manual" by *Loose Ends*. Mostly on unusual hand made papers. Another is the *Wood Parts Catalog* from *Lin-Wood*. Who do make a bewildering array of small wooden items.

Or, just because it is there I guess, the neat free *Things You Never Knew Existed* catalog from *Johnson Smith*.

For typical individuals and small scale startups most of the time, any involvement whatsoever with patents is absoutely certain to turn into a net loss of your time, energy, money, and sanity. You find out why in my *Case Against Patents* package. It includes proven real world alternatives.

See my nearby *Synergetics* ad for more details. I've also got some great deals on Tek 1230A logic analyzers left over from my school buyout.

I'm still building my web site at *www.tinaja.com* Eventually, globally searchable reprints for my previous columns should be available here.

Check this one out.

As usual, a no-charge tech helpline and online access is available per the *Need Help* box. Most of the resources mentioned appear in our *Names and Numbers* or *Pro Audio* sidebars.

Let's hear from you. ✦