Three Phase Magic Sinewaves

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The Issue...

Magic Sinewaves offer maximized efficiency with minimized low harmonics for emerging power electronics applications. Per these **tutorials**.

But ordinary magic sinewaves are not three phase compatible because they would need extra drivers, equipment rewiring, and have other restrictions.

Fortunately, a special class of **Delta Friendly** magic sinewaves can instead be generated that can end up fully three phase compatible.

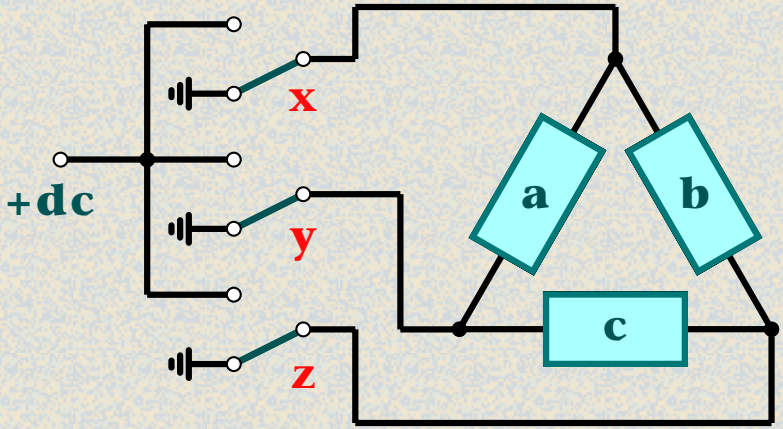
Delta Friendly Features...

- Fully three-phase compatible.
- Lengths of n=12, 28, 44, 60, 76,... available.
- Zero out the first (3n/4) + 1 harmonics.
- Table lookup storage only one-half of usual.
- Analysis and design is faster.

Why Three Phase Power?

- Power flow is continuous.
- Motors start and reverse easier.
- Less noise and vibration.
- Smaller wiring sizes.
- Better use of copper and iron.

Delta Friendly Switching…



Eight Allowable Switch States...

z	y	x
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

Produce These Current Patterns…

z	y	x	c= a+240°	b= a+120°	a= a+0°
0	0	0	0	0	0
0	0	1	0	cw	ccw
0	1	0	ccw	0	cw
0	1	1	ccw	cw	0
1	0	0	cw	ccw	0
1	0	1	cw	0	ccw
1	1	0	0	ccw	cw
1	1	1	0	0	0

To ALWAYS force a zero average!

z	y	x	c= $a+240^o$	b= $a+120^o$	a= $a+0^o$	sum
0	0	0	0	0	0	zero!
0	0	1	0	cw	ccw	zero!
0	1	0	ccw	0	cw	zero!
0	1	1	ccw	cw	0	zero!
1	0	0	cw	ccw	0	zero!
1	0	1	cw	0	ccw	zero!
1	1	0	0	ccw	cw	zero!
1	1	1	0	0	0	zero!

The Key Delta Friendly Rule…

Because of the permissible switching combinations…

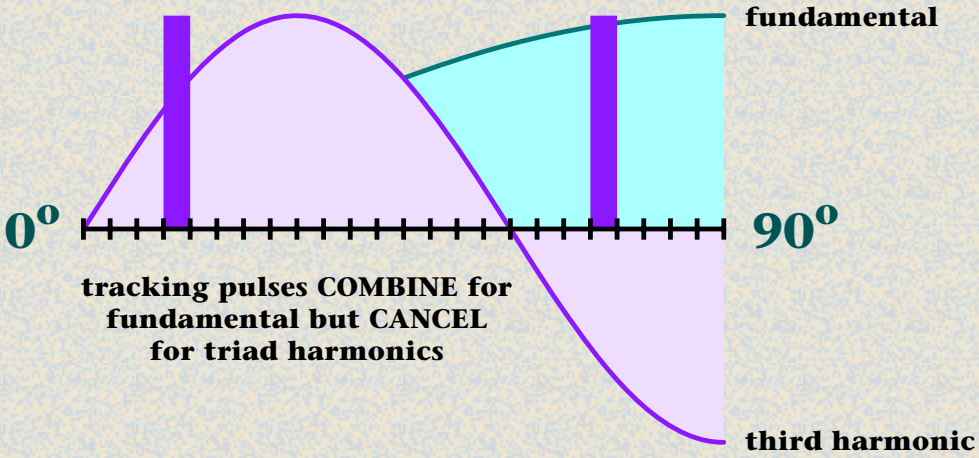
All triad samples
MUST sum to zero!

Which leads to this strict rule…

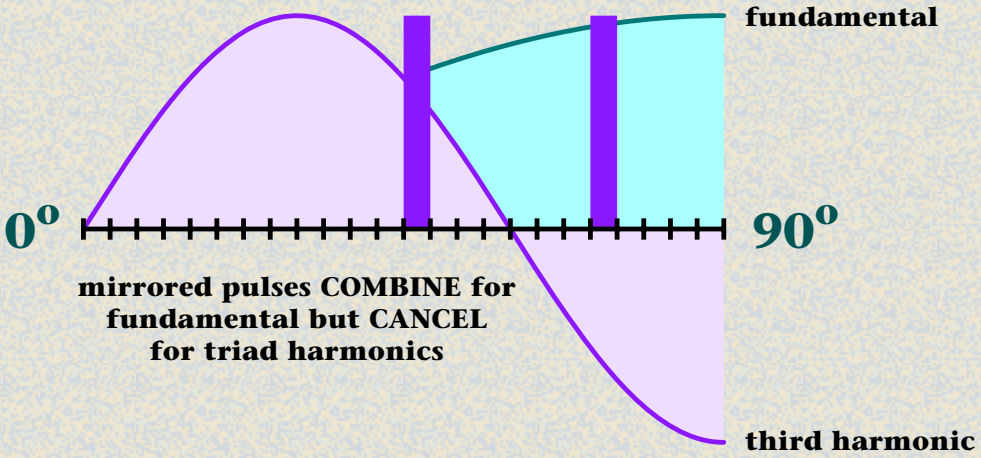
NO TRIAD HARMONICS!

Thus, delta friendly magic sinewaves **must** have precisely **zero** 3rd, 9th, 15th, 21st, … harmonics.

This Works...


fundamental
0°
90°
tracking pulses COMBINE for fundamental but CANCEL for triad harmonics
third harmonic

So Does This...


fundamental
0°
90°
mirrored pulses COMBINE for
fundamental but CANCEL
for triad harmonics
third harmonic

Leading to our Delta Design rules…

- If there is ZERO energy in a narrow interval **x** in the 60 to 90 degree region of the first quadrant, then there must also be ZERO energy in intervals **x-60** and **120-x**.
- If there is ONE energy in a narrow interval **x** in the 60 to 90 degree region of the first quadrant, then there must also be ONE energy in EITHER interval **x-60** OR in the interval **120-x**. But not both.

Delta Friendly Synthesis Starts…

… by picking a number **k** of **whole** and **bounded** pulses placed in the 60 to 90 degree quadrant interval…

value of k	pulses per quadrant	edges per quadrant	pulses per cycle n	harmonics zeroed
1	3	6	12	10
2	7	14	28	22
3	11	22	44	34
4	15	30	60	46
5	19	38	76	58
k	(4k-1)	2(4k-1)	4(4k-1)	(12k-2) = (3n/4)+1

With a Goal of…

… creating **one** equation for **each** available first quadrant pulse edge. Specifically…

- **One half of the pulse edges get used as edge tracking for zero triad harmonics.**
- **One pulse edge will set the amplitude.**
- **Remaining pulse edges zero 5, 7, 11, 13, 17, 19, … non-triad odd harmonics.**

Ferinstance...

On a delta friendly **n=28** Magic Sinewave, there are **fourteen** first quadrant pulse edges.

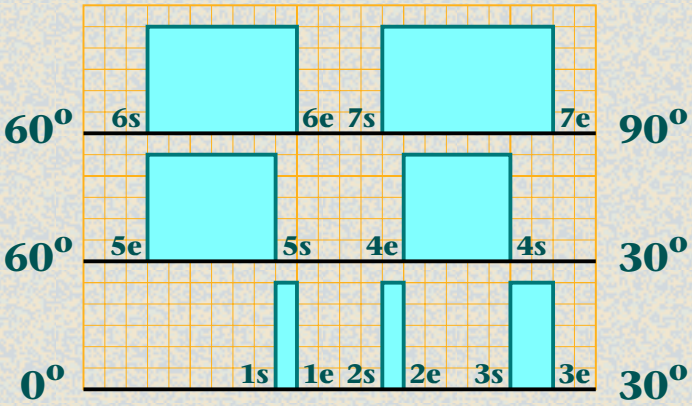
One edge sets the amplitude. Seven edges zero out all triad harmonics **3**, **9**, **15**, **21**, **27**... and will guarantee three phase compatibility through **edge tracking**.

Six edges zero harmonics **5**, **7**, **11**, **13**, **17**, & **19**.

Harmonics **23** and **25** will end up fairly strong.

Continue Synthesis with Wrap Map…

Arrange your pulses into a **wrap map** of **(2k-1)**, **k**, and **k** pulses. The map **must** obey the delta rules…



Wrap Map Guidelines...

- Vertical positions MUST have ZERO or TWO pulses.
- The 60 to 30 interval INCREASES to the LEFT.
- Initially center k pulses in 60 to 90 interval.
- Left 60 to 30 pulse aligns LEFT. Rest CENTER.
- Left 0 to 30 pulse aligns RIGHT. Rest BY PAIRS.
- PAIRS of pulse edges must be perfectly aligned.

Write the Tracking Equations…

Pairs of pulse edges found from the wrap map must be locked together for tracking in order to eliminate all of the triad harmonics…

p1s = 60 - p5s

p1e = p6e - 60

p2s = p7s - 60

p2e = 60 - p4e

p3s = 60 - p4s

p3e = p7e - 60

p5e = 120 - p6s

Then Write the Full Equations...

Shown for a "**n=28**" delta friendly Magic Sinewave. Because of edge locking, there will be only seven **independent** equations in seven unknowns. Only **one-half** of the normal storage is needed.

$$\cos(1*p1s)-\cos(1*p1e)+\ldots+\cos(1*p7s)-\cos(1*p7e) = ampl*\pi/4$$
$$\cos(5*p1s)-\cos(5*p1e)+\ldots+\cos(5*p7s)-\cos(5*p7e) = 0$$
$$\cos(7*p1s)-\cos(7*p1e)+\ldots+\cos(7*p7s)-\cos(3*p7e) = 0$$
$$\cos(11*p1s)-\cos(11*p1e)+\ldots+\cos(11*p7s)-\cos(11*p7e) = 0$$
$$\cos(13*p1s)-\cos(13*p1e)+\ldots+\cos(13*p7s)-\cos(13*p7e) = 0$$
$$\cos(17*p1s)-\cos(17*p1e)+\ldots+\cos(17*p7s)-\cos(17*p7e) = 0$$
$$\cos(19*p1s)-\cos(19*p1e)+\ldots+\cos(19*p7s)-\cos(19*p7e) = 0$$

Equation Solution...

These equations can be elegantly solved by using **These JavaScript Calculators**, in a variation of **Newton's Method**.

A guess is made to get you near a trial solution. Additional passes are then made to significantly improve the previous result.

The process rapidly converges to an exact desired amplitude and precise zero harmonics.

For Additional Help…

Magic Sinewave **calculators** and tutorial…

http://www.tinaja.com/magsn01.asp

Magic Sinewave **development** proposal…

http://www.tinaja.com/glib/msinprop.pdf

Magic Sinewave **seminars** and consulting…

http://www.tinaja.com/info01.asp

This has been...

... a presentation by Don Lancaster and **Synergetics**, 3860 West First Street, Box 809, Thatcher, Arizona, 85552. (928) 428-4073.

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