An Introduction to Magic Sinewaves

By Don Lancaster
and Synergetics

http://www.tinaja.com

Magic Sinewaves are…

A new class of mathematical functions that promise to significantly improve the efficient generation of power digital sinewaves for…

- **AC motor speed controls**
- **Electric vehicles**
- **Power quality conditioners**
- **Telephony & datacomm**
- **Solar energy conversion**
- **400 Hertz Aerospace apps**
- **Battery Powered Inverters**

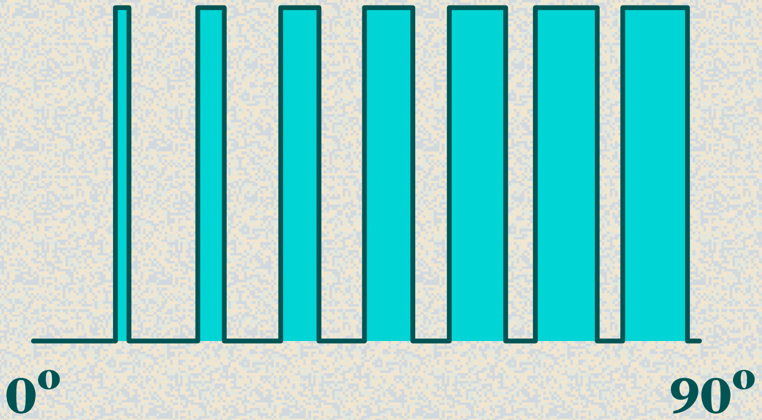
Magic Sinewave Features...

- Fewest switch events for highest efficiency.
- Any chosen number of low harmonics are zero.
- All digital and highly low end micro friendly.
- As few as seven values stored per amplitude.
- Precise control of amplitude and frequency.
- Can be made fully three phase compatible.
- Half-bridge switching events for low loss.

And Limitations…

- Generation must be precise.
- Some output filtering is required.
- Load matching is recommended.
- Wide speed range does not extend to dc.
- Best suited for low audio frequencies.
- First two uncontrolled harmonics are large.

Magic Sinewave Appearance …

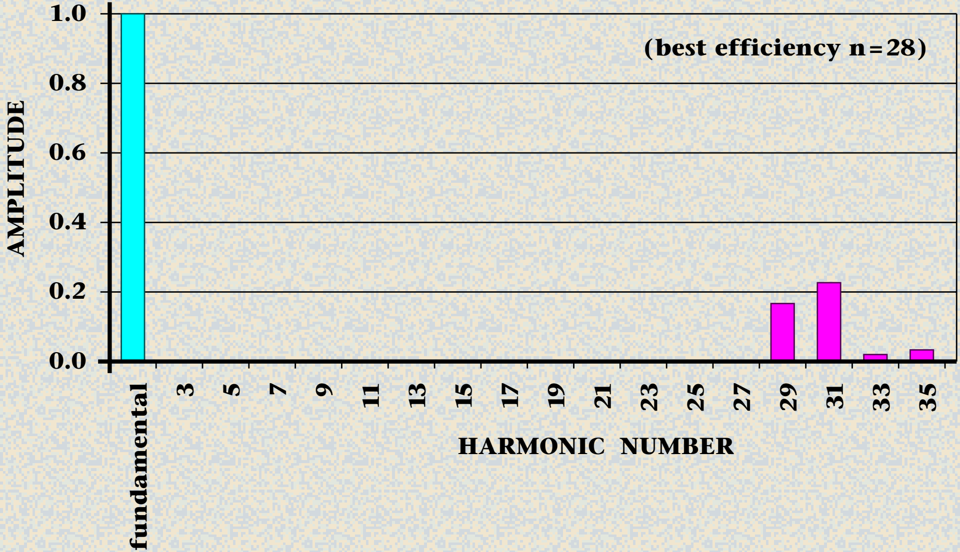


Working in Quadrants...

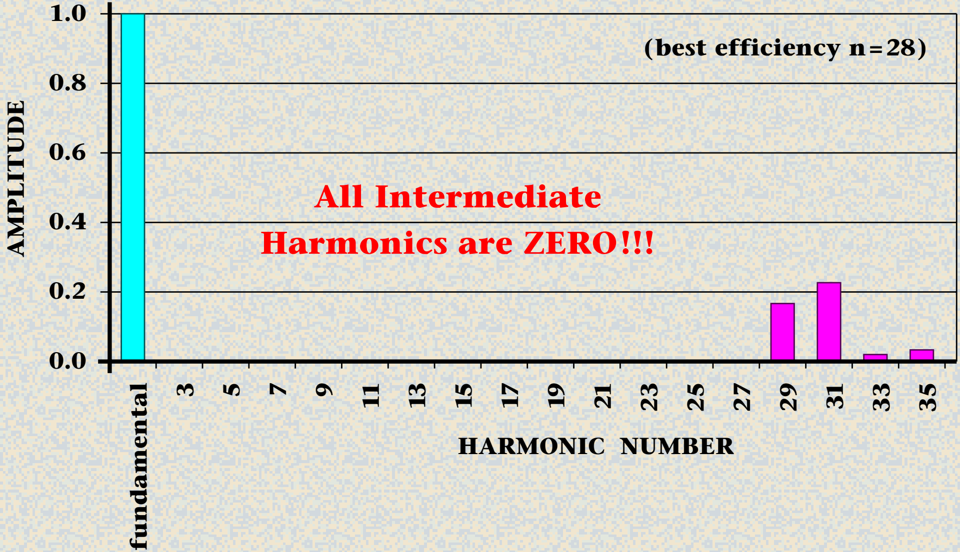
Normally, only the first quadrant of a magic sinewave is generated. This is then mirrored or reflected to form the full sinewave. The first quadrant design benefits include...

- **No even harmonics.**
- **No odd cosine harmonics.**
- **No dc term.**
- **One quarter the data storage.**
- **Much faster analysis.**

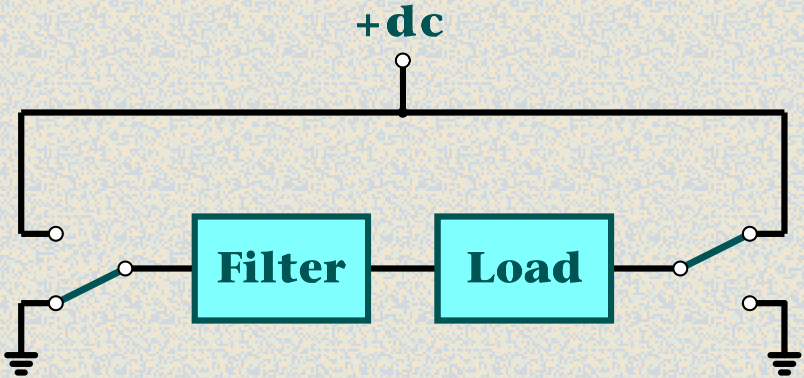
Typical Unfiltered Spectrum...



Typical Unfiltered Spectrum...



Magic Sinewave Generation...



Note that…

The magic sinewave synthesis process **guarantees** maximum low harmonic rejection for any given number of switching events.

When compared to classic PWM…

- **There are far fewer switching events.**
- **Events are half bridge for lower loss.**

Two Important MagSine Types...

Best Efficiency:

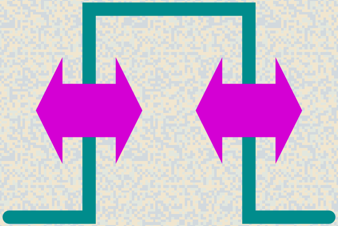
- Zeros out first n harmonics.
- n/2 values stored per amplitude.
- Single phase only.

Delta Friendly:

- Zeros first (3n/4) + 1 harmonics.
- n/4 values stored per amplitude.
- Fully three phase compatible.

The Key MagSine Secret (I)...

By way of an esoteric math transform…



…Each quadrant pulse edge (indirectly) performs **one** useful task. Thus providing you the maximum possible efficiency by minimizing switch events.

Key MagSine Secret (II)...

(Example #1)

On a best efficiency 28 Magic Sinewave, there are **fourteen** first quadrant pulse edges.

One edge sets the amplitude. Thirteen edges zero out harmonics **3**, **5**, **7**, **9**, **11**, **13**, **15**, **17**, **19**, **21**, **23**, **25**, and **27**.

Unfiltered harmonics **29** and **31** will be fairly strong, but always will be less than the fundamental.

The Key MagSine Secret (III)...

(Example #2)

On a delta friendly 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 be fairly strong.

Fourier Pulse Properties…

Given a unity height first quadrant pulse starting at angle **p1s** and ending at an angle of **p1e**, its fundamental amplitude contribution will be…

cos(1*p1s) - cos(1*p1e) = ampl*pi/4

And its harmonic **j** contribution will be…

cos(j*p1s) - cos(j*p1e) = ampl*pi/4j

The Magic Equations...

(shown for best efficiency Magic Sinewave "**n=20**")

cos(1*p1s)-cos(1* p1e)+...+cos(1*p5s)-cos(1*p5e) = ampl*pi/4

cos(3*p1s)-cos(3*p1e)+...+cos(3*p5s)-cos(3*p5e) = 0

cos(5*p1s)-cos(5*p1e)+...+cos(5*p5s)-cos(5*p5e) = 0

cos(7*p1s)-cos(7*p1e)+...+cos(7*p5s)-cos(3*p5e) = 0

cos(9*p1s)-cos(9*p1e)+...+cos(9*p5s)-cos(3*p5e) = 0

cos(11*p1s)-cos(11*p1e)+...+cos(11*p5s)-cos(11*p5e) = 0

cos(13*p1s)-cos(13*p1e)+...+cos(13*p5s)-cos(13*p5e) = 0

cos(15*p1s)-cos(15*p1e)+...+cos(15*p5s)-cos(15*p5e) = 0

cos(17*p1s)-cos(17*p1e)+...+cos(17*p5s)-cos(17*p5e) = 0

cos(19*p1s)-cos(19*p1e)+...+cos(19*p5s)-cos(19*p5e) = 0

Equation Simplification...

These equations can be dramatically simplified by noting that trig multi-angles are really one common form of **Chebycheff polynominal**.

A most interesting property of many Chebycheff polynominals is that when they are really good at something, they are often the best possible.

Thus driving the Cheby to the Levy.

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.

Quantization...

Exact magic sinewave solutions require **extreme** math accuracy. Quantization effects will raise the harmonics to low rather than zero values.

Very often, ten bits of timing info will give "acceptable" results, while twelve bits should yield "good" results.

Some **"smoke and mirror" techniques"** may be needed to allow eight bit timing storage.

Clocking Frequencies...

Many events have to sequentially take place to properly generate a Magic Sinewave. The number and precision of the events sets the clocking rate.

Typically, a **4 MegaHertz** clocking gives useful **60 Hertz** Magic Sinewaves.

It is often best to separate the frequency setting from the actual Magic Sinewave generation.

How Big Should "n" Be?

For most uses most of the time, a best efficiency or delta friendly **n = 28** will be optimum. This will zero up to **28** harmonics using as few as **seven** values of table lookup storage per amplitude.

Very large values of "**n**" will require more switch events but allow very wide speed ranges, may reduce audio whine, greatly ease filtering, and still provide benefits over classic PWM.

Zeroing **several thousand** harmonics is possible!

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.

mailto:don@tinaja.com