An Introduction to Magic Sinewaves

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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**
- **Aerospace apps**

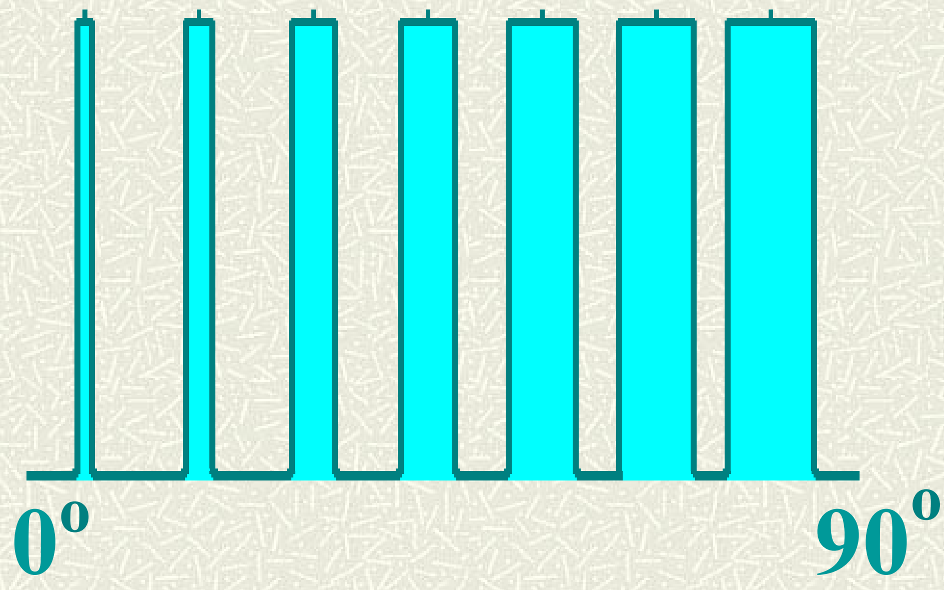
Magic Sinewave Features…

- **Highest efficiency through fewest switch events.**
- **Any chosen number of low harmonics are zero.**
- **All digital and fully low end micro friendly.**
- **As few as seven value storage per amplitude.**
- **Fine control of amplitude and frequency.**
- **Can be made 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…

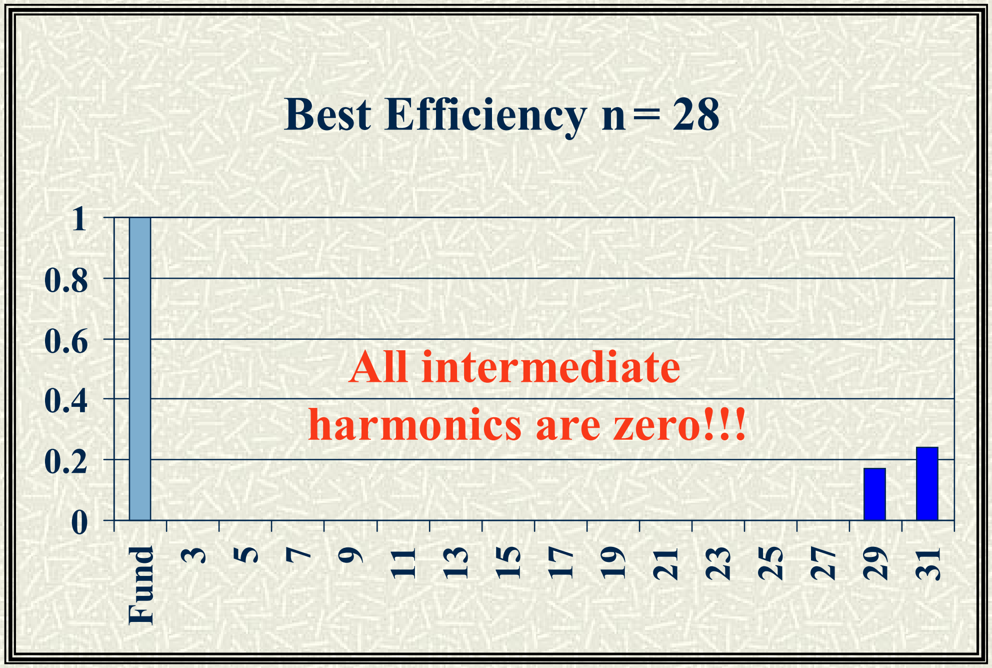


Working in quadrants…

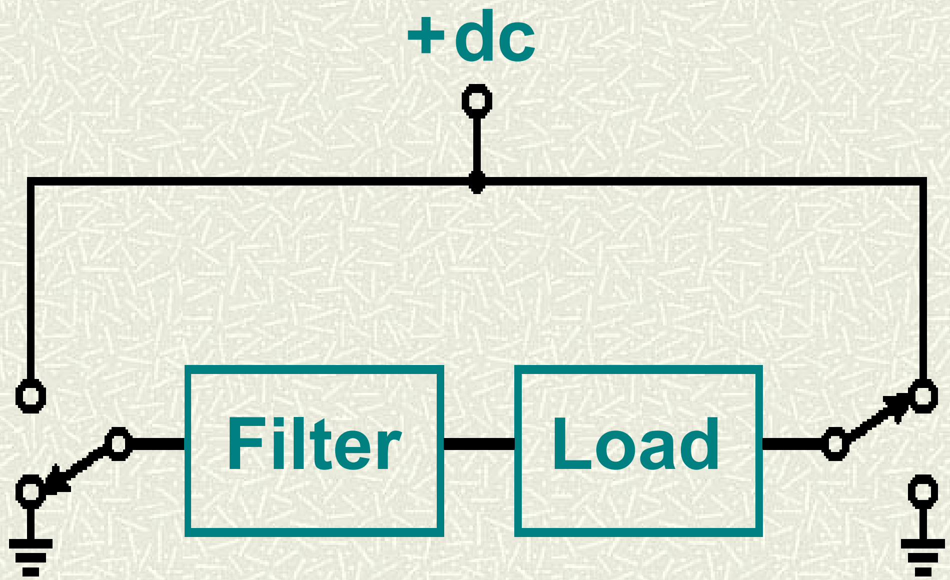
Normally, only the first quadrant of a magic sinewave is generated. This is then mirrored or reflected to form the full sinewave. The first quadrant design benefits include…

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

Typical Unfiltered Spectrum…



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:

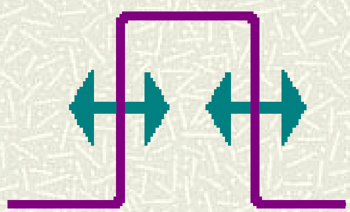
- **Zeros out first n harmonics**
- **n/2 values stored per amplitude.**
- **Single phase only.**

Delta Friendly:

- **Zeros first (3n/4) + 1 harmonics.**
- **Only 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 the maximum possible efficiency by minimizing switch events.

The 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.

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.

Six edges zero harmonics 5, 7, 11, 13, 17, & 19. Harmonics 21 and 23 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 (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 Chebycheff polynominals is that when they are good at something, they are often the best possible.

Thus driving the Cheby to the Levy.

Equation Solution…

These equations are elegantly solved by using Newton’s Method, aka “shake the box”.

A guess is made to get you near the solution. A pulse edge is then moved slightly to see if the distortion gets better or worse.

The process repeats for all pulse edges till you get as close to a solution as you want to.

Amplitude Adjustment…

When a zero harmonic magic sinewave solution is found, the final amplitude may not be exact.

This is corrected by asking for a slightly larger or smaller amplitude.

For instance, if you want .400 and get .396, ask for .404 instead. Convergence is often rapid.

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. values.

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 size 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.

For Additional Help…

Magic Sinewave calculators and tutorials…

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, AZ, 85552.

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