Filter-Free Synthesis of Digital Power Sinewaves?

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Magic Sinewaves are a newly discovered class of mathematical functions that hold significant potential to dramatically improve the efficiency and power quality of solar energy synchronous inverters, electric hybrid automobiles, and industrial motor controls, among many others. An executive summary can be found **here**, a slideshow type intro presentation **here**, a development proposal **here**, the latest calculator **here** with its tutorial **here**, demo chips **here**, and more info **here**.

Major goals of such digital sinewave generation including offering the **maximum possible efficiency** by using the fewest of simplest possible switching transitions; offering the **lowest possible distortion** by zeroing out a maximum number of low harmonics that impact power quality, whine, vibration, and circulating currents; and by using **all digital techniques** that are extremely low end micro friendly.

Magic sinewaves have two remarkable properties: **Any number of desired low harmonics can be forced exactly to zero** in theory, and to astonishingly low levels when quantized to 8-bit compatible levels. And magic sinewaves use the **absolute minimum possible and simplest energy-robbing transitions** to achieve such harmonic suppression.

Can Filtering be Eliminated?

A typical magic sinewave shares a common problem with any other power digital sinewave synthesis scheme: Besides the desired fundamental, there will be "sharp edges" to deal with. Undesired switching transitions of remaining uncontrolled harmonics. With magic sinewaves, the energy in these undesired remaining uncontrolled harmonics can be made quite high in frequency.

Low pass filtering is normally used to separate what is wanted from what is unwanted. Sometimes this filtering can simply be the inductance of a motor or an inertial load. Other times, elaborate tracking schemes may be needed.

A key question is whether we can eliminate low pass filtering entirely. Leaving us with a "pure list" of switch flips, an output fundamental, any number of forced zero harmonics, and **everything else of negligible amplitude**.

The counterintuitive and surprising "too good to be true" answer appears to be that we can in fact create harmonic suppression situations that leave us with very little undesirable harmonic energy. And that the distinct possibility of low pass filter elimination (or at least its dramatic reduction) exists.

At present, only partial example solutions exist. But solutions clearly good enough to study further here in detail. Solutions ones highly useful for real world apps.

We will arbitrarily call a "filter free" solution any one that leaves us with very a few uncontrolled or undesirable very high frequencies harmonics of amplitudes less than **one tenth** the fundamental and energies less than **one hundredth** the fundamental. While filtering may still be advisable (especially for wide range motor speed controls), at the very least it should be greatly simplified at these energy and frequency levels.

Two Examples

Let's look at two **magic sinewave** examples that behave pretty much normally by themselves. But have the remarkable property of apparently offsetting and thus **suppressing** their carrier energies **when used in progressive quadrants**.

Consider first a "regular" magic sinewave of eight pulses per quadrant. The spacing of our pulses will be constant and their positioning will be symmetric both about **and centered on** the zero and 90 degree axes. Pulses will get "fatter" as you approach 90 degrees of fundamental.

An older and somewhat glacial calculator (scheduled for revision) can be found **here** that will let you analyze this magic sinewave in depth. We will set our magic sinewave to **0.6** fundamental amplitude. All low order harmonics up through the **30th** will be forced to zero in theory and to astonishingly low values when quantized to values consistent with 8-bit microcontrollers.

Our eight pulse start and stop angles for **0.6** amplitude and thirty zeroed low harmonics will be…

Original 8 pulse Magic Sinewave, amplitude = 0.6...

pulse #1	**5.6502959306 start**	**6.29225152936 end**
pulse #2	**15.8186279820 start**	**17.71453042722 end**
pulse #3	**26.2633360096 start**	**29.36133313031 end**
pulse #4	**36.8410803264 start**	**41.04778015351 end**
pulse #5	**47.5658943498 start**	**52.74756810010 end**
pulse #6	**58.4640633843 start**	**64.44315460533 end**
pulse #7	**69.5556070049 start**	**76.10701844505 end**
pulse #8	**80.8431647264 start**	**87.69588876333 end**

As noted, our fundamental amplitude will be **0.6** and our low harmonics **2** through **30** will be automatically forced to zero. Our first four **uncontrolled** harmonics of concern are ...

h31 = 0.70119349921
h33 = -0.49857579402
h35 = -0.21908625461
h37 = -0.02988268814

Quite obviously, our first uncontrolled **31st** harmonic of **0.70119349921** of our fundamental amplitude is significant and will demand low pass filtering if this magic sinewave is used in its normal stand-alone manner.

The next bunch of harmonics will be "small" and our next item of concern will likely be the **61st**. In general, taking care of **h31** through **h37** will also pretty much take care of all of the higher ones.

A Possible Suppressing Sequence

Next, consider an "alike but different somehow" magic sinewave of the **bridged best efficiency** style. This will also be eight pulses per quadrant, set to **0.6** amplitude, and will identically force low harmonics **2** thru **30** to zero.

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Compared to our original magic sinewaves, our BBE pulses are in somewhat different positions, strangely "interleaving" the pulses of our previous original magic sinewave solution...

Bridged Best Efficiency 8 ppq Magic Sinewave, 0.6 amplitude...

pulse #1	**10.4353438671 start**	**11.7077750493 end**
pulse #2	**20.9101395432 start**	**23.4181541929 end**
pulse #3	**31.4636502516 start**	**35.1329284465 end**
pulse #4	**42.1342741421 start**	**46.8514916513 end**
pulse #5	**52.9576520410 start**	**58.5675969212 end**
pulse #6	**63.9624867662 start**	**70.2640240671 end**
pulse #7	**75.1632563302 start**	**81.9072380861 end**
pulse #8	**86.5515348716 start**	**90.0000000000 end**

Even more surprising are our first uncontrolled harmonics...

h31 = -0.71971577316
h33 = 0.47421202953
h35 = 0.21303620988
h37 = 0.03024943268

Note that these harmonics are almost equal in magnitude but opposite in sign to those of our original magic sinewave for the same amplitude!.

Now, what if…

What if…

What if we used an ordinary **n=8** magic sinewave for one quarter of a fundamental cycle, producing an **0.6** amplitude and zeroing out the first **30** harmonics. And then we used a bridged best efficiency n=8 magic sinewave for the next quarter of a fundamental cycle, producing an **0.6** amplitude and zeroing out the same **30**low harmonics. And then repeated continuously as needed?

Would the average of our unsuppressed harmonics also average out to their half cycle values? Specifically "**disintegrating**" to their difference?

If so, then a dramatic reduction in unwanted harmonic strength would result through cyclic suppression. Caused by the fundamental difference in how carriers are used in creating the pulse positions for the two differing magic sinewave types. Specificlly…

Instead of h31 being -0.7197 or 0.7011, would its half wave average be 0.0086?

Instead of h33 being 0.4742 or = -0.4985 would its half wave average be 0.0243?

Instead of h35 being 0.2130 or = -0.2190 would its half wave average be 0.0060?

Instead of h37 being = 0.0302 or -0.0298 would its half wave average be 0.0004?

All of which would give us the potential of filterless digitally synthesized sinewaves. Lists of start and stop angles that zero out chosen low harmonics and only have negligible energy elsewhere.

Some Extensions

All of this has a "too good to be true" air about it, but preliminary verification seems encouraging, some third party support has been received, and absolute experiments are in process. Your input to this development is strongly encouraged.

Things get even better below **0.6** amplitude, so the method should work for amplitudes from **0.0** up through **0.6**. Above **0.6**, performance **of this specific example** rapidly becomes progressively worse. But we might ask "**0.6 of what?**" We may have the option of making **0.6** amplitude our normal "full scale" output in fact being the system maximum. And suitably adjusting currents or turns ratios otherwise.

What utterly and totally boggles the mind is that this is just one example involving just one pair of serendipitiously stumbled into quadrant matched and paired magic sinewaves. There is no reason that many more and much better alternatives abound.

It does appear that entire new classes of filterless digitally synthesesized power sinewaves that go far beyond magic sinewaves themselves may in fact emerge.

For More Help

Further **Magic Sinewave** explorations require your participation as a Synergetics **partner** or **associate**.

To proceed, view the many **Magic Sinewave** tutorial files and JavaScript calculators you'll find at **http://www.tinaja.com/magsn01.asp**.

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