PLD-BASED GENERATION OF SPECIAL WAVEFORMS WITH LOW THIRD HARMONIC CONTENT

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ABSTRACT

A PLD-based digital waveform generator has been developed. Standard waveforms, such as: sinewave, triangular and squarewave, found in any function generator, are already pre-defined. The user may also create his own waveforms, by specifying the amplitude for each step and the frequency. The waveform is displayed on a GUI; the PC transfers the waveform to the generator board, which is controlled by a PLD. One special application is the generation of a special waveform with low third harmonic content. This waveform is used in non-linearity measurements of resistors, as recommended by IEC/TR 60440 standard.

1. INTRODUCTION

Waveform synthesis has been of interest in many areas of electronics. One such area is power inverter systems, where harmonic suppression is required. Another example is the measurement of third harmonic content to determine the linearity of passive components, as recommended by IEC/TR 60440 standard[1].

Waveforms can be generated with analog and digital techniques. In the digital side one can calculate sinewave amplitudes and store the data in RAM. During operation, the data is read through a digital-to-analog converter (DAC) with a precision clock. In such techniques, one is trying to generate a perfect sinewave. By increasing the number of samples, number of bits (DAC) and clock stability, one reduces all harmonics. However, in the case of linearity determination, it is not necessary to suppress all harmonics, because is only necessary to measure the third harmonic. Based on this fact, it is proposed a special waveform with low third harmonic content. The paper is divided in four sections, first this introduction, second the arbitrary waveform board and control software, third the special waveform is described and fourth, the conclusions.

2. ARBITRARY WAVEFORM BOARD AND CONTROL SOFTWARE

In Figure 1, is shown the simplified waveform generator diagram. It has a programmable peripheral interface to communicate with the host computer through the ISA bus; a PLD to control the board and event synchronization; an SRAM chip to store all amplitudes in a multiple integer of the period; and a high-speed 12-bit DAC with an output buffer. It can generate arbitrary waveforms with amplitudes in the -10V to 10V range, and frequencies in the 1 to 100kHz range. Through the graphical interface, developed in Delphi, the user chooses among pre-defined waveforms, such as sinusoidal, exponential, square, triangular. Arbitrary waveforms can also be generated. For all waveforms, one can change the amplitude, frequency, offset and duty-cycle, by using virtual knobs and keyboard. The created waveform may also be saved in a ".txt" file.

The control software downloads this information to the board memory and configures the PLD. The PLD chip (EPM7128) was programmed in AHDL[2]. In the PLD, it was implemented a counter, a programmable 16 bit-timer to synchronize the memory scan, and the control logic.

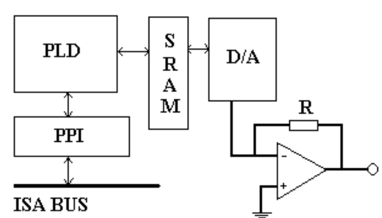

Fig. 1. Simplified waveform generator diagram

3. WAVEFORM GENERATION WITH LOW THIRD HARMONIC CONTENT

One application of the board described above is to generate a waveform with low third harmonic content. To study this concept, a special waveform has been included in the control software. In the next paragraphs, the waveform is presented.

A general integrable periodic function, f(t), with no DC component, can be written as a Fourier series. If f(t) is odd and f(t) = - f(t+T/2), one can write f(t) as:

$$f(t) = a_1 \sin ù\, t + a_3 \sin 3ù\, t + a_5 \sin 5ù\, t + K \qquad (1)$$

The objective is to reduce a_3 to zero. Preferably, this should be accomplished with a waveform which can be stored in digital format.

3.1. Ideal case

Consider the odd periodic function with N steps. The requirement that f(t) = - f(t+T/2) forces N to be even. For t > 0:

$$f_{ideal}(t) = \begin{cases} V_1 & 0 < t < \frac{T}{N} \\ V_2 & \frac{T}{N} < t < \frac{2T}{N} \\ M & \\ V_N & (N-1)\frac{T}{N} < t < T \end{cases} \qquad (2)$$

Philip D. Corey[3] proposed two waveforms with reduced harmonic content up to some order depending on de number of steps. His application is static inverters. In the limit of N infinite, the waveforms proposed by Corey [3] are sinewaves. For the first waveform, the amplitudes from 2 to N are chosen, such as:

$$V'_k = \frac{V'_1}{\sin(ö/2)} \sin\,(k - 1/2)\,ö \qquad (3)$$

where, $ö = 2\pi / N$.

For the second waveform, the amplitudes from 2 to N are chosen, such as:

$$V''_k = \frac{V''_1}{\sin(ö/2)} \sin\,(k - 1/2)\,ö \qquad (4)$$

To have odd symmetry in time domain, the second waveform is shifted by ö/2. As an example, consider N=6. A sketch of the waveforms obtained are presented in Figure 2.

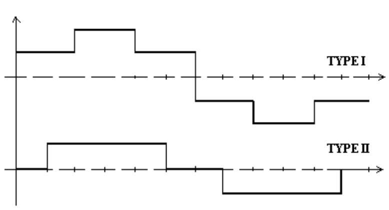

Figure 2. Type I and II waveforms for N=6

3.2. Real case

For real world circuits, not considered by Corey[3], transitions are not abrupt. One has also to take into account the number of steps and the number of bits of the counter, and the slew rate of the op-amp. Due to the non-idealities, the third harmonic is no longer necessarily zero. It is proposed to perform a linear combination of the two previously defined waveforms, and adjust the combination to achieve the lowest third harmonic content possible. Notice that combination of waveforms with N steps will generate a waveform with 2N steps.

The combined waveform can be adjusted by selecting the parameters p and q, such as:

$$q = 1 - |\,p\,| \; and \quad p = -1..1 \qquad (5)$$

Then, the combined waveform is given by:

$$Vc[i] = p * V'[i] + q * V''[i] \qquad (6)$$

3.2. Results

The plot in Figure 3 presents the third harmonic distortion of the combined waveform versus the parameter p for N=6 and N=32. The measurements are obtained with an HP 54602B digital scope.

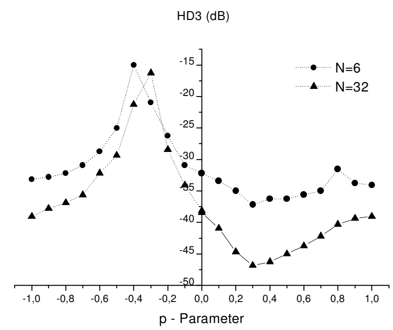

Figure 3. Third harmonic distortion for N=6 and 32

The results demonstrate that by selecting an appropriate value for the parameter p, one can reduce the third harmonic content. The HD3 of the combined waveform varies from -37dB to -15dB for N=6. In this case, type I and II have a HD3 equal to -33dB, which gives us a effective gain of -4dB. For N=32, the combined wave has a HD3 from -47dB to -15dB, and the effective gain is -9dB. Although, the third harmonic is not zero, its reduced by adjusting the parameter p and using a small number of steps.

4. CONCLUSIONS

We have presented a low cost waveform digital generator, based on PLD. The generator board and control software are flexible due to the use of AHDL[2] and object-oriented programming language. As an application, we have implemented a special waveform with low third harmonic content.

5. REFERENCES

[1] http:// www.iec.ch
[2] http:// www.altera.com
[3] P. D. Corey, "Methods for optimizing the waveform of stepped-wave static inverters' ' , AIEE Summer General Meeting, paper 62-1147, 17th June, 1962.