Signal Windowing Models Implementation Comparison for Signal Analysis in a SBCD (Brazilian Data Collection System) Satellite Transponder Project

Everton Jose de Souza[1], V. A. O. Martins[1,2] and Renan Toniolo[3]
[1] CI - BRASIL – Centro de Treinamento - SP
[2] PPGEE, USP - Universidade de São Paulo
[3] UNITEC Semiconductors
e-mail: {evertonjsouza, viniciusomartins, toniolo.renan}@gmail.com

1. Abstract

*W*indowing is a technique used to reduce the spectral leakage observed when performing signal spectral analysis over a non-coherent sampled signal. This paper presents a discussion on effects of the different windowing techniques affects the performance of the FFT frequency analysis on a SoC designed as part of signal recovery of a SBCD(Brazilian Data Collection System) satellite transponder project.

Keywords— System on a Chip; Digital Signal Processing; Fast Fourier Transform.

2. Introduction

In a Digital Signal Processor (DSP) it is common to make use of many techniques to avoid loss of signal analysis integrity due to mathematical artifacts, so that the output gets as close as possible to an ideal response. One of these techniques is windowing, which is a simple mathematical adjustment on a set of samples, so that the signal spectra analysis gets a more accurate response reducing the frequency peaks leakage.

This paper show a part of results achieved on project of a SBCD (Brazilian Data Collection System) Communication Transponder SoC designed by C.I. BRASL Training Centers.

In this paper, section II will present a brief description of the windowing technique and features. Section III will present the reasons used to choose the most adequate windowing technique for the project. Section IV will present experimental results. Finally, section V will present the conclusion of the windowing application. This paper will show the results of timing and area of three different windowing techniques.

3. Windowing Technique

The windowing technique is a way used to improve the spectral analysis of a sampled signal in order to make more accurate to detect a specific frequency. The usage of discrete time frequency analysis when using a non-coherent sampling approach brings truncation related problems due to the mathematical definition of discrete time Fourier transform (DFT). Actually, the DFT is applied to a finite data sequence is a two steps approach. First, a window is applied over a data stream to select an N long data sequence. This operation corresponds to a multiplication of the entire data sequence by one N times and padding zero on all remaining data. The resulting windowing signal spectra correspond to a convolution of the window and the actual data spectrum. This mathematical process brings the effect of spreading the data frequencies over its own vicinity frequencies.

Therefore, the window appropriate selection may the spectral spread by doing a simple mathematical operation with the input signal. This is a simple technique that multiplies the signal by a function that "zero" the extremes to turn signal periodic on a specific time and multiply by a specify function, seeking to satisfy FFT periodicity requirement and highlights some spectral features.

As shown in Ref [1] there are many windowing types. The most known ones are Rectangular, Hanning, Hamming, Kaiser-Bessel, Triangular and Flap-top window. However, this paper presents an analysis with three of them:

A. *Rectangular windowing*

The rectangular windowing is defined by the equation 1. This type of windowing do not modify the shape of original signal.

$$w(n) = 1 \qquad (1)$$

B. *Triangular windowing*

The triangular windowing is defined by the equation 2. This type of windowing can be used to reduce the spectral spread. Due to its spectra content, it introduces spikes near a frequency with a high amplitude level.

$$w(n) = 1 - \left|\frac{n - {}^{N}/_{2}}{{}^{N}/_{2}}\right| \qquad (2)$$

Where, n is the sample number and N the total number of samples.

C. *Hann or Hanning windowing*

The Hann or Hanning windowing is defined by the equation 3. This type of windowing can be used to reduce the spectral spread effect.

$$w(n) = 0.5 - 0.5 * cos\left(\frac{2\pi n}{N}\right) \qquad (3)$$

Where, n is the sample number and N the total number of samples. Its function shapes is shown in fig.1

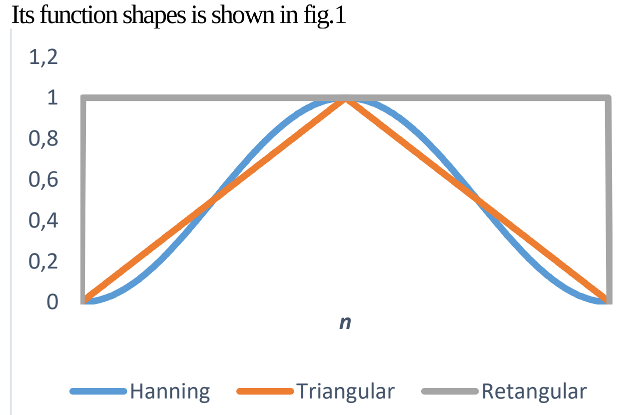

***Fig.1.** Windowing shapes*

4. Windowing Technique Selection

The triangular and Hanning windows aims to minimize the effects caused by the rectangular window. Each of the windowing techniques aims to reduce the effects of leakage. In fact, they change the shape of the leakage according to window frequency distribution. Generally, each type of windowing technique will affect the spectrum in a different way. The best type of windowing technique should be chosen by analyzing the features of the system input signal.

Evaluating the features of the input system signal, the most indicated windowing technique is Hanning, because this type of window has small side interference, making it easier to find two frequencies near to each other with high difference of amplitudes. When comparing the Hanning window with other complex window functions, it can be observed that the complex window functions generate more hardware (due to the mathematical complexity), therefore increasing the final chip area.

5. Experimental Results

In order to evaluate the window technique results, a signal model and a signal processing system was created (fig. 2). It has three functional blocks, the Window block; the Fast Fourier Transform (FFT) block, used to transform the input signal to the frequency domain and a block to compute the modulus of the signal called Magnitude such in the Fig. .

The Magnitude block is responsible for extracting from the FFT output signal the absolute value. The feature of this signal is get according the equation 4.

$$magdata = \sqrt{fftdatareal^2 + fftdataimag^2} \qquad (4)$$

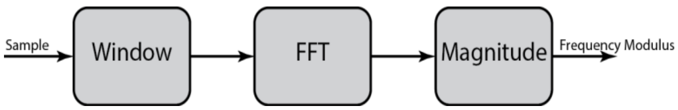

Fig. 2. System Block Diagram

The hardware was designed on Verilog HDL, using fixed-point arithmetic with 10 bits (1 bit for the integer, plus 9 for the decimal part). The data width is restricted on the project due to the transponder's Analog to Digital Converter (ADC) construction.

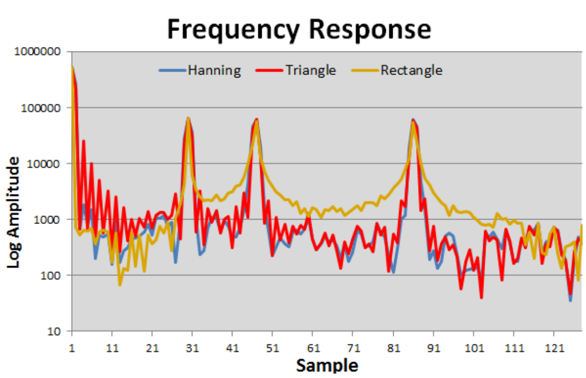

Fig. 3 shows the frequency response of the same signal, with four frequency components combined, while applying different windowing techniques.

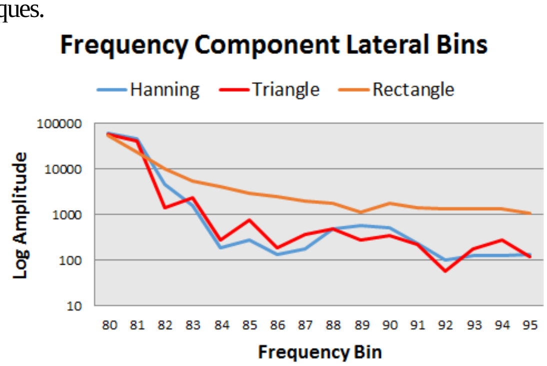

Fig.4. Frequency Component Lateral Bins

To make it easier to spot the differences between the different responses, Fig.4 shows the frequency response in detail of the fourth component (centered at sample 80).

With these data, it is possible to analyze the windowing leakage attenuation when compared to the simple rectangular window.

6. Logic Synthesis Results

To analyze the different window impact on area, it was made a logic synthesis using:

- Tool: Cadence® Encounter RTL Compiler v.11.12
- Technologic library cells: XFAB 180nm D_CELLSL_MOSST_typ_1_80V_25C V2.2.0

The logic synthesis was applied only to the windowing block, since. The Hanning Window block implementation uses a CHIPWARE IP CW_cos, this IP generate the cosine of an input angle.

The comparison of area reports are shown in Fig.5 . Hanning is ~300% and ~248% bigger than Triangular in area and number of cells, respectively.

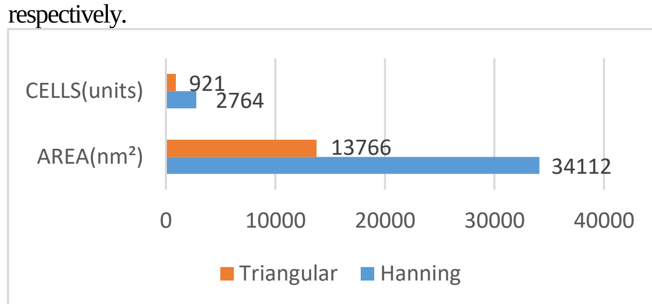

***Fig.5.** Window cells area and Window cells amount*

7. Conclusion

The windowing process using Hanning and Triangle functions showed a significant enhancement on the FFT output, by attenuating the input signal's leakage effect. Although, when comparing the FFT outputs, it was observed that, regarding the transponder project specifically, Hanning and Triangular techniques presented similar leakage attenuation.

The cause of this similarity of results when comparing both techniques occur because the used model of signals has power at spaced frequencies far enough, the powers used were in low frequencies (35 to 150 KHz) and in this range the frequency responses of windowing mentioned above are similar and the data width has low precision.

When the logical synthesis is applied to these cases, it can be observed that the number of digital cells used was considerably higher on the Hanning window than the Triangular window. This fact results in a considerable increase in chip area and power consumption when actually the results do not show a better leakage attenuation.

So, in this context and for reasons above mentioned, Hanning was replaced by Triangular windowing in project.

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