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Application of Distortion Reduction in FIR Filters in Dynamic Systems through Computational Methods

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***Abstract*— The article shows a development methodology in the operation of finite impulse response (FIR) digital filters when built on computational methods based on general use processors.**

***Key Words*- Digital Filter, Digital Signal Processing, Low Pass Filter.**

I. INTRODUCTION

Digital systems generally contain advantages when compared to analog systems; among those features are elements such as high reliability, flexibility of system upgrades and cost-related issues. In addition to this feature, there is a growing number of applications that use large integration scale technology (4). As a result of many computational applications requiring frequent changes in their functionality or an increase in behavioral flexibility, it is often possible to rapidly built prototypes for digital systems. In this article, we seek to develop an FIR digital filter from a modified Hamming window (1), wherein the computer system is based on a queue where the first elements inserted are the first to be removed (FIFO).

II. FIR DIGITAL FILTER

An FIR filter can be represented by Equation 1.

$$y[k] = \sum_{n=0}^{N-1} \mathrm{h[n]} * \mathrm{x[k-n]} (1)$$

Where *x* represents the input signal, *h* represents the filter coefficients and *y is* the result, i.e., the filtered output signal. In this implementation, a series of multiply-accumulate (MAC) operations are applied to each sample of the input signal; this occurs by multiplying the *N* input samples by the system coefficients and finally adding the results for obtaining the output signal (2).

III. FIFO

FIFO is a special type of list characterized by how its elements are inserted or removed. In a queue, the first elements inserted are the first to be removed (first in, first out), characterizing the original term FIFO. The architecture of a FIFO structure can be demonstrated in Figure 1.

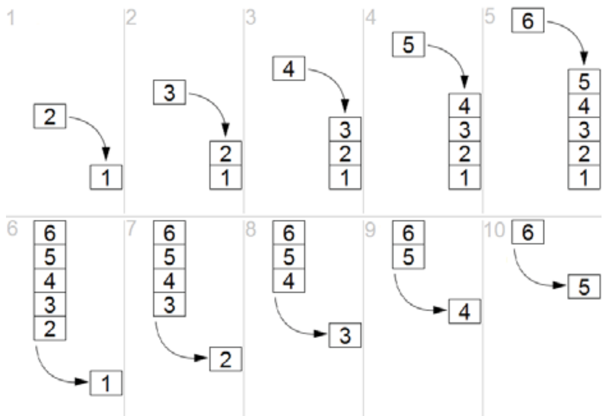

Figure 1. Architecture of a FIFO structure.

IV. SYSTEM ARITHMETIC

In digital filters, it is possible to develop alternative structures that do not apply the use of multipliers directly. These systems use distributed arithmetic (2), where the sum of products between the filter coefficients and the input signals is made without multipliers. In this way, the hardware is minimized, as well as consumption (6). This technique can be seen in Equation 2.

$$y[k] = \sum_{i=0}^{B-1} \left(\sum_{n=0}^{N-1} h(n) * b_{k-n,i} \right) * 2^{-i} + \left(\sum_{n=0}^{N-1} h(n) * -b_{k-n,0} \right) (2)$$

Where $b_{k,i}$ are bits 0 or 1 of signal $x(n)$ represented in two's complements with $(B+1)$ bits and $b_{k,0}$ the sign bit.

V. FILTERS HAVING WINDOW

Digital filters having window apply rejections at undesired points in the system at present lobules, i.e., those that are not acceptable beyond the main lobe. This phenomenon occurs due to having frequencies that are not required for that filter. In the proposed development, the modified Hamming window will be used as seen in equation 3.

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$$w[n] = [0{,}54 - 0{,}46^{nx-1}\cos(\frac{2^{nx-1}\pi n}{M})] + [0{,}54 - 0{,}46^{nx-2}\cos(\frac{2^{nx-2}\pi n}{M})] + [0{,}54 - 0{,}46^{nx-3}\cos(\frac{2^{nx-3}\pi n}{M})] + [0{,}54 - 0{,}46^{nx-mx}\cos(\frac{2^{nx-mx}\pi n}{M})] \quad (3)$$

Where factor 2π represents the entire spectrum of the radian axes. The technique allows the insertion of new points in the windowing; this occurs by dividing the 2π radian spectrum into smaller points in order to more efficiently produce a filter. This occurs with the implementation of an *n*-th polynomial applied to 2π in addition to the 0.46 factor in order to maintain linearity.

VI. APPLICATION OF DISTORTION REDUCTION IN FIR FILTERS BY APPROXIMATION THROUGH WINDOW FACTOR ON FUNCTION COEFFICIENTS

The development of a low-pass filter having Hamming window computationally consists in implementing a FIFO structure in which its coefficients are accumulated in the time domain and multiplied by the calculated filter coefficient (5). The example shown in Figure 2 consists of a low-pass filter having Hamming window, with cut-off frequency 1Hz and sampling frequency 100Hz. To that filter, 136 coefficients are applied to a signal that emulates a harmonic developed by using an approximation sequence of the number π.

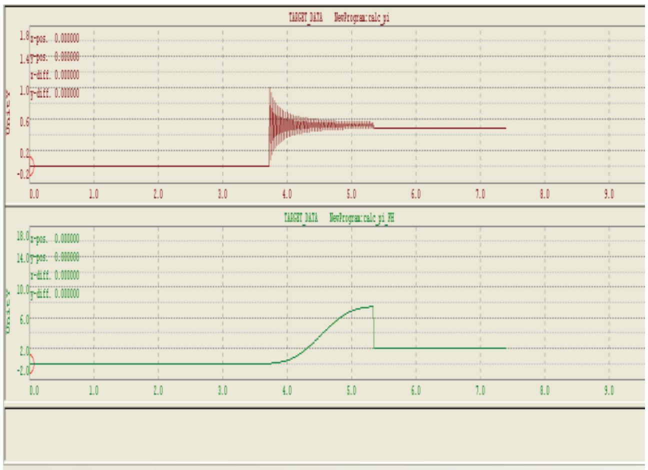

Figure 2. Filter having Hamming window in the time domain.

Figure 3 shows the same computational implementation cited in Figure 2 with the modification of the calculated coefficients according to Equation 3. This will demonstrate the increase in linearity and speed of convergence to the target point.

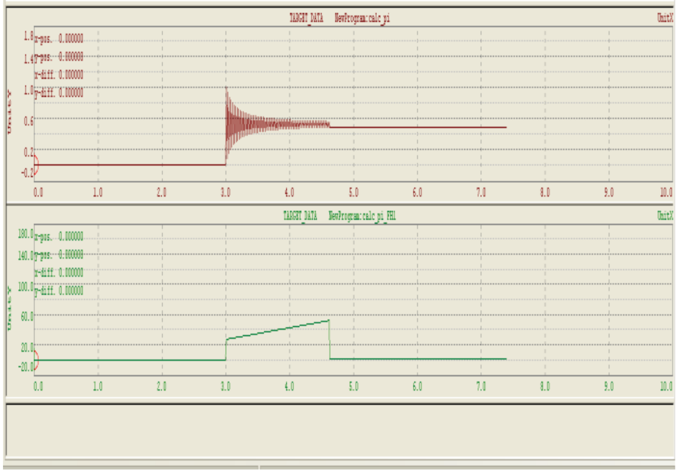

Figure 3. Filter having modified Hamming window in the time domain.

Figure 4 shows the same computational implementation mentioned in Figures 2 and 3 with a computational modification that proposes not to apply the filters to the first samples, causing the response to accelerate with respect to the target point. This effect increases the capacity of repeatability of the system by virtue of providing samples that are more stable in time.

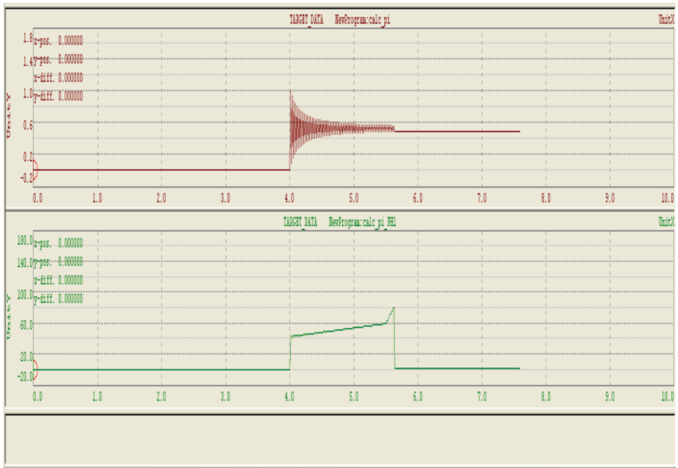

Figure 4. Filter having modified Hamming window in the time domain with computational methods.

VII. CONCLUSION

The implementation of Equation 3 with the computational changes aiming to have a no-action rejection window of the filter causes the system to have a much more effective conversion to the target point; as a downside, it is possible to notice the occurrence of a peak at the end of the sample due to the amount of samples rejected early in the process. With the implementation of averages, this phenomenon may be easily remedied, as well as the reduction in the number of coefficients rejected by the filter early in the process.

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