Designing and Performance Analysis of Canonic Signed Digit Filters

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Abstract— In this paper, design and performance analysis of canonic signed digit (CSD) filters on the aspect of power consumption, area required, hardware complexity and speed of the filters which can be easily implemented in hardware applications especially for wireless communication applications where higher order filters are often required to meet the channel attenuation specifications. The expected results of this study will show reduction in power consumption upto 33% than the binary representation of the filters when implemented using the SIMULINK software which increases the efficiency of the filters. Also, results show reduction in area required to design filters when implemented on the FPGA kit and therefore, hardware complexity will reduced to a great extent.

***Key words*:** canonic signed digit; FIR filter; Hann window; Simulink

I. INTRODUCTION

Filter eliminates the harmful constituent from signal. The unwanted factor generates the noise in the signal so that system could not work properly and don't cater accurate information of the system. Filter is used to filter these noise signals and generate a noise less signal. This noise less signal provides accurate information of the system. Different-different digital filter are used in many fields like communication, image area, medical area etc. These digital filters furnish more accuracy and improve the result of signal. There are several methods available for the design of filters. In this paper we study the merits and demerits of different approach[1].

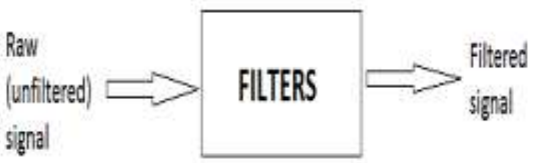

Fig. 1: Function of digital filter

On a multiplierless structure, the main source of power consumption is the additions[3]. Several algorithms with the aim of reducing the number of adders needed in such a structure have been presented in literature. Among the efficient algorithms[3] are:

[1] Reducing the number of additions needed by taking advantage of common sub-expressions (CSE).
[2] Exploiting the reduction of non-zero bits in different number representations.
[3] Representing the multiplication as a graph-structure.
[4] Implementing the design in a Distributed Arithmetic manner on a FPGA.

Canonic signed digits[4] (CSD) have two properties:

1. Minimal representation
2. Unique representation

II. RELATED WORK

As the multipliers and adders are the main source of power consumption in filters.CSD is a technique in which the coefficient is based on canonical signed digit (CSD), which minimizes the number of adder/subtractor used in each coefficient multiplier. The aim of CSE algorithm is to identify multiple event of identical bit patterns present in coefficients to remove the redundant multiplications which results in considerable reduction of adders as well as the complexity of FIR filter compared to the conventional implementation.

A. Related Algorithm

The csd[4] representation is one of the existing signed digit representations with unique features which make it useful in certain DSP applications focusing on low-power, efficient area and high speed arithmetic. Canonic signed digit is based on a ternary number system (1, 0, -1). It is a unique representation of binary number with minimum number of 1 and -1. It allows minimum number of addition and subtraction to produce the product. In this we have to convert the multiplier coefficient from 2's compliment to its equivalent CSD representation. Due to the ternary nature each non zero digit in a CSD representation requires two bits one for magnitude and one for sign hence there is a need for extra space. From the definition it can be mathematically represented as[2]

$$X = \sum_{i=0}^{n-1} X_i 2^i \quad \text{where } X_i \in -1, 0, 1$$

The important characteristics of the CSD presentation are:

1) CSD presentation of a number consists of numbers 0, 1 and -1.
2) The CSD presentation of a number is unique.
3) The number of nonzero digits is minimal.
4) There cannot be two consecutive non-zero digits.

B. Design steps

The design steps for the purposed canonical signed digit (CSD) algorithm are as follows:

1) First, find the binary presentation of the number.
2) Starting from the right (LSB), if you find more than non-zero elements (1 or -1) in a row, take all of them, plus the next zero. (if there is not zero at the left side of the MSB, create one there).
3) Add 1 to the number (i.e. change the 0 to 1, and all the 1's to 0's), and force the rightmost digit to be -1.
4) Now, check that the number is still the same.
5) If there are no more consecutive non-zero digits, the conversion is complete.

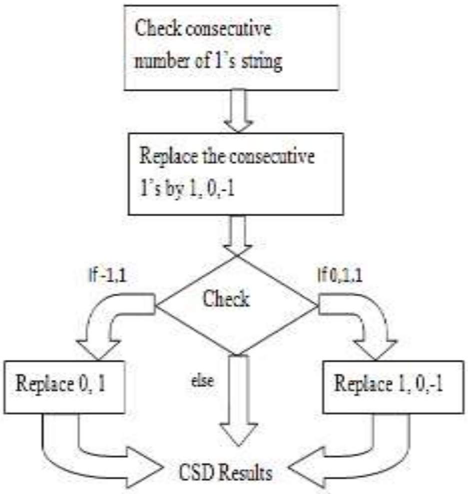

Fig. 2 : Flow chart of 2's compliment.

C. Filter Design

With the help of above equation, given below model is designed in the SIMULINK

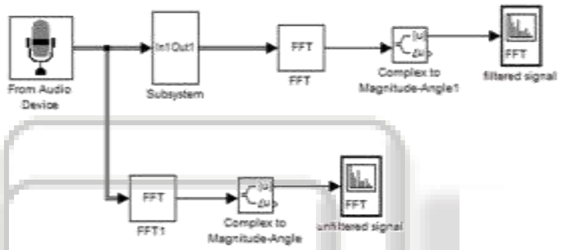

Fig. 3: filter model

Subsystem block is created by selecting all the blocks and then in the main menu, click on the edit and then on the create subsystem option. By this, a subsystem is created. On double clicking the subsystem, in the new window designed filtered is opened which can be shown as below in the figure.

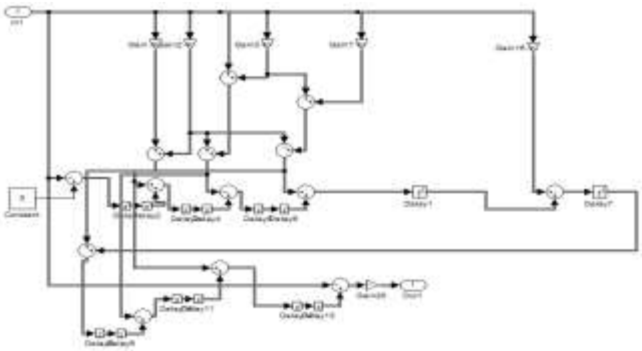

Fig. 4: Subsystem block

D. Modified Filter Design

In this, delay elements are inserted between adders which act as the part of the multiplication so that critical path can be reduced. The order of the shifter and the delay element is reversed and the delays having the same input are unified. By this, the number of delay elements is reduced by an equivalent transformation.

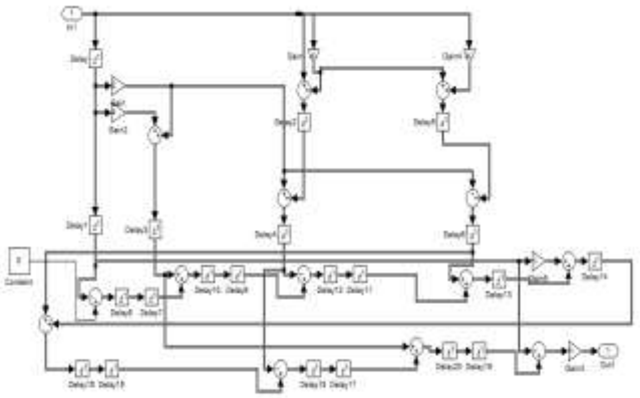

Fig. 5: Modified Subsystem Model

III. SIMULATION RESULTS

The designed filtel model is simulated using the Simulink from which two spectrums are obtained one for the unfiltered signal (original signal) and the other for the filtered signal.

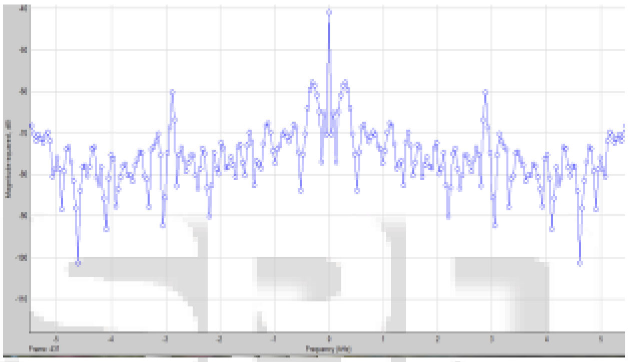

Fig. 6: Unfiltered signal spectrum

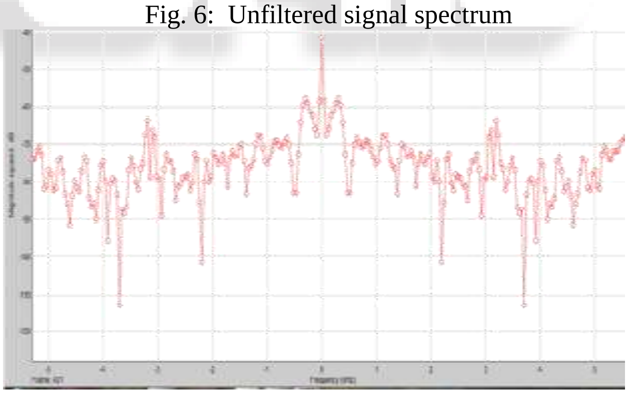

Fig. 7: Filtered signal spectrum

On magnifying the spectrum of the unfiltered signal and the filtered signal, the values of the magnitude of the both signals are tabulated for the different frequency. In the table, a comparison is made between the unfiltered signal and the filtered signal in which frequency is in kHz and magnitude is in decibels (db).

S. No.	Frequency (kHz)	Unfiltered Signal Magnitude (db)	Filtered Signal Magnitude (db)
1.	0	-41	-41
2.	0.1	-69	-68
3.	0.2	-61	-61
4.	0.3	-59	-59
5.	0.4	-67	-68

6.	0.5	-80	-82
7.	0.6	-69	-70
8.	0.7	-70	-70
9.	0.8	-70	-70
10.	0.9	-72	-71
11.	1	-78	-75
12.	2	-75	-76
13.	3	-82	-79
14.	4	-75	-74
15.	5	-77	-78
16.	6	-73	-70
17.	7	-77	-79
18.	8	-78	-80
19.	9	-81	-84
20.	10	-81	-81

Table. 1: Comparison between unfiltered and filtered signal magnitude

The given below table shows the comparison between the sideband magnitudes of the unfiltered signal and the filtered signal of the spectrum. For the different sidebands, the magnitudes of the both signal spectrum is noticed. The given below table represents the magnitude values for the ten sidebands

S.No.	Sideband	Unfiltered Signal Magnitude (db)	Filtered Signal Magnitude (db)
1.	1st	-66	-59
2.	2nd	-58	-69
3.	3rd	-68	-69
4.	4th	-70	-68
5.	5th	-67	-70
6.	6th	-78	-71
7.	7th	-70	-72
8.	8th	-72	-74
9.	9th	-77	-71
10.	10th	-71	-79

Table. 2: Comparison between sideband magnitudes

The given below table shows the comparison between the number of sidebands of the unfiltered signal and the filtered signal present in the spectrum. For the different frequency ranges, number of sidebands in the both spectrum are noticed.

S.No.	Frequency (kHz)	In Unfiltered Signal	In Filtered Signal
1.	0 – 1	4	3
2.	0 – 2	9	7
3.	0 – 3	14	11
4.	0 – 4	18	15
5.	0 – 5	23	19

Table. 3: Comparison between sideband magnitudes

The given below table represents the comparison between the cut – off frequencies of the unfiltered signal and the filtered signal spectrum. For the different cut – off frequency e.g.1st, 2nd,…etc., the respective frequency of the both signal spectrum is noticed. The given below table shows the values for the five cut – off frequencies

S.No.	Cut – off Frequency	Unfiltered Signal Frequency (kHz)	Filtered Signal Frequency (kHz)
1.	1st	0.05	0.09
2.	2nd	0.14	0.48
3.	3rd	0.5	0.7
4.	4th	0.72	1
5.	5th	1	1.39

Table. 4: Comparison between sideband magnitudes

IV. CONCLUSION

This thesis study focuses on the designing of digital filter using proposed CSD algorithm. This design algorithm uses two techniques. Out of which one technique is the CSD based technique and the other is the modified CSD technique in which the critical path is reduced. In the FIR low pass filter designing using CSD technique, the amplitude of the filtered signal is less as compared to the unfiltered signal. Also, in the filtered signal the cut-off frequency is 0.09 kHz and in the unfiltered signal the cut-off frequency is 0.05 kHz that is, the cut-off frequency is increased in filtered signal as compared to the original signal. As the frequency increases, the number of sidebands and the amplitude of sideband are increased and decreased respectively in the filtered signal. For the same frequency range for the both unfiltered signal and the filtered signal, the number of sidebands are more in the unfiltered signal as compared to the filtered signal that is number of sidebands decreases in the filtered signal.

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