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Review of Cascaded Integrator- Comb (CIC) FIR filters with Passband Compensation

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ABSTRACT: Multirate filters find application in communication, speech processing, image compression, antenna systems, analog voice privacy systems and in the digital audio industry. The cascaded integrator-comb filter is a digital filter which employed multiplier-less realization. This type of filter has extensive applications in low-cost implementation of interpolators and decimators. The basic principles of the CIC decimation filter are presented in this paper. It combines the cascaded integrator-comb (CIC) multirate filter structure with compensation techniques to improve the filter's passband response. This allows the first- stage CIC decimation filter to be followed by the FIR decimation filter. Simulation results show the gain responses of the CICfilters.

KEYWORDS: Cascaded Integrator-Comb (CIC) filter, sampling rate conversion, decimation, FIRdecimation

I. INTRODUCTION

Cascade Integrator-Comb filters are proposed by Eugene B. Hogenauer [1] and are widely used as decimation or interpolation filters since then. As the name describes, CIC filter is a cascade of integrators and comb filters. Decimation in applications like AID converters is usually done intwostages where M and V are respectively, the decimation factors of the first and second decimation stages [2]. P=M.V is the oversampling factor as shown in Fig. l. The first stage employs a CIC filter and the second stage uses a usual FIR filter which works at low sampling rate. The decimation factor V decides the passband frequency and stopband frequency of the first stage CIC decimation filters.
Cascaded-integrator-comb (CIC) decimation filter [3] is a simple multiplier-less filter providing high folding-band attenuations. However, such a response is paid with a high passband droop. To reduce the droop, several structures have been proposed. The most popular structure is based on connecting a finite-impulse-response (FIR) filter called compensator in cascade with the CIC filter. Since the CIC filter is multiplier-less, the compensator with multiplier-less realization is preferable aswell.
During the last decade, various multipliers-less CIC compensators for improving narrow and wide passbands have of coefficients. Multiplier-less compensators with three coefficients are commonly used [5]. They efficiently improve narrow passbands. However, for wideband applications requiring significant droop reduction, multi-stage compensators or single-stage compensators with five coefficients are more appropriate. To meet the passband requirements, wideband compensators usually require rather complexstructures.

II. CASCADED INTEGRATOR-COMB (CIC) FILTERS

The cascaded integrator-comb (CIC) filter is a class of linear phase finite impulse response (FIR) digital filters. CIC-filters achieve sampling rate decrease (decimation) and sampling rate increase (interpolation) without using multipliers. A CIC-filter consists of an equal number of stages of ideal integrator and comb filters. Its frequency response may be tuned by selecting the appropriate number of cascaded integrator and comb filter pairs. The highly symmetric structure of a CIC-filter allows efficient implementation. The disadvantage of a CIC -filter is that its pass-band is not flat, which is undesirable in many applications. This problem can be alleviated by a compensation filter. The transfer function of the CIC-filter in z-domain is given in equation (1)[3].

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$$H(Z) = (\frac{1 - z^{-k}}{1 - z^{-1}})^{L} \qquad (1)$$

In Equation (1), K is the oversampling ratio and L is the order of the filter. The filter H(Z) can be implemented by cascading the comb section.

CIC-Filters in Decimation:-

The CIC-filters are utilized in multirate systems for constructing efficient decimators and interpolators. The comb filter ability to perform filtering without multiplications is very attractive to be applied to high rate signals. Moreover, CIC filters are convenient for large conversion factors since the low pass bandwidth is very small. The multirate application of comb filters has been proposed first by Hogenauer, and since that time, the so-called Hogenauer filters.

CIC-Filters in Interpolation:-

The CIC interpolator is implemented as a cascade or K differentiators (comb) sections, factor-of-N down sampler, and the cascade of K integrators.

III. LITERATUREREVIEW

Kanika Mehta et al. [1], a novel class of CIC FIR jilter functions has been developed recently which preserves the simpleness of classical CIC FIR Filters by avoiding multipliers but shows improvement in stopband attenuation. In this paper, a compensator jilter has been used to reduce the passband drop of the novel class of CIC jilter functions. The compensator performs effectual compensation using three additions/subtractions. Examples are shown to compare the passband response of novel class of CIC jilters and novel class of compensated CIC jilters. Comparison between stopband attenuation of classical CIC jilter functions and the novel class of compensated CIC jilter functions is also shown through these examples.

Azadeh Safari et al. [2], Discrete wavelet change (DWT) has demonstrated awesome execution in computerized picture pressure and denoising applications. It is the change utilized for source encoding as a part of JPEG2000 still picture pressure standard and FBI wavelet scalar quantization. DWT is fit for quick picture pressure at less region and low power utilization. This paper displays 4-tap orthogonal DWT in view of the buildup number framework. Equipment unpredictability lessening and configuration change are attained to by utilizing RNS for number-crunching operations and LUT offering between low pass and high pass channels. The RNS based DWT is reenacted and executed on the Xilinx FPGA to confirm the usefulness and effectiveness of theoutline.

Yajun Zhou et al. [3], the present examination paper portrays a system assessing the Field Programmable Gate Array (FPGA) assets usage for execution of computerized channels with distinctive requests. For a low pass Butterworth channel, barring its request, rest of the configuration parameters were kept steady. Channel outlining was done utilizing the numerical figuring environment programming, MATLAB. Its exceptional office producing Hardware Description Languages (HDLs) for a computerized channel item was conveyed. Diverse Very High Speed Integrated Circuit HDL (VHDL) source codes were created and executed in Xilinx FPGA gadget Spartan-3E by expanding channel request, until the gadget usage surpasses the accessible assets. Thusly, a most extreme 18th request channel was implementable in FPGA. The computerized channel reaction was shown on an Oscilloscope by method for a microcontroller, Advance RISC Machine (ARM) gadget LPC2148. The simple to advanced and computerized to simple transformation over advanced channel information was performed in a solitary ARMchip.

V. Sudhakar et al. [4], this paper displays completely parallel and completely serial architectures for Band pass channel. The exhibitions of completely parallel and completelyserialarchitectures are investigated for distinctive quantized adaptations of representation. Channels produced utilizing 8 bit settled point execution requires littler zone utilization when contrasted with 16 bit altered point usage at the expense of imprecision. The proposed executions are

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orchestrated with Xilinx ISE 13.2 rendition. Group of gadget was Spartan 3E and target gadget was xa3s250e-4vqgl00. The key execution measurements, to be specific number of Slices, Slice Flip Flops, LUTs, Maximum recurrence areanalyzed.

Animesh Panda et al. [5], A channel may be obliged to have a given recurrence reaction, or a particular reaction to a motivation, step, or incline, or recreate a simple framework. Contingent upon the reaction of the framework, computerized channels can be ordered into Finite Impulse Response (FIR) channels & Infinite Impulse Response (IIR) channels. FIR Filters can be composed utilizing recurrence examining or windowing routines. Yet these strategies have an issue in exact control of the basic frequencies. In the ideal outline system, the weighted estimate lapse between the real recurrence reaction and the sought channel reaction is spread over the pass-band and the stop-band and the greatest blunder is minimized, bringing about the pass-band and the stop-band having swells. The crest mistake can be processed utilizing a PC supported iterative methodology, known as the Remez ExchangeAlgorithm.

IV. PROPOSEDMETHODOLOGY

Two novel classes of selective CIC filter functions with improved response have been discussed in the previous chapter, which shows improvement in stopband attenuation of classical CIC filter functions for the same number of cascade sections and the same value of decimation factor. Therefore, these filters can replace the first stage decimation filters and enhance the stopband attenuation characteristics of lower order filters, with order less thanabout.

However, there is a drawback in these novel classes of CIC filter functions. The passband response of these novel classes of CIC filters is not flat and there is a drop in the passband characteristics. To overcome this drawback, a simple sine- based compensator is introduced in this chapter. This compensator performs effective compensation using three additions/subtractions and without using any multipliers.

Droop-Compensation filter:-To reduce the passband drop of the novel classes of CIC filters, a simple and effectual compensation filter is used. The magnitude response of compensation filter is defined by

$$\left| G(e^{j\omega M}) \right| = \left| 1+2^{-d}\sin^2\left(\frac{\omega M}{2}\right) \right| \qquad (2)$$

Wheredisasuitableintegerbelongingtoset{-2,…,2},andω is related to digital frequency f through $\omega = 2\pi f$. By making use of the very well-knownidentity.

$$\sin^2\beta = \frac{1-\cos 2\beta}{2} \qquad (3)$$

$$G(z^M) = C\left[1+Dz^{-M}+z^{-2M}\right]$$

The corresponding transfer function is of the form (4)

The constant C is a scaling factor ensuring unity gain at the digital frequency zero. It is defined in power-of-2 form as

$$C = -2^{-(d+2)} \qquad (5)$$

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$$D = -\left(2^{d+2}+2\right)$$

(6)
This compensation filter needs only three additions/subtractions and it has one unknown variable d.

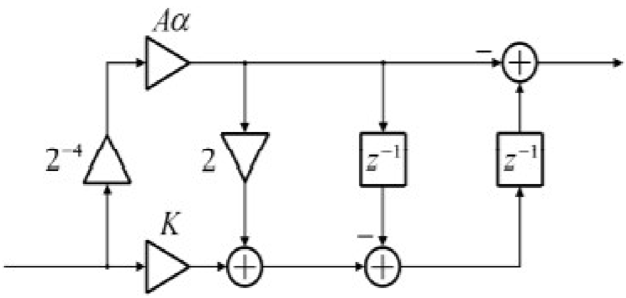

Figure 1: Structure of multiplier-less compensator withthree coefficients for sharpened CIC filter of secondorder.

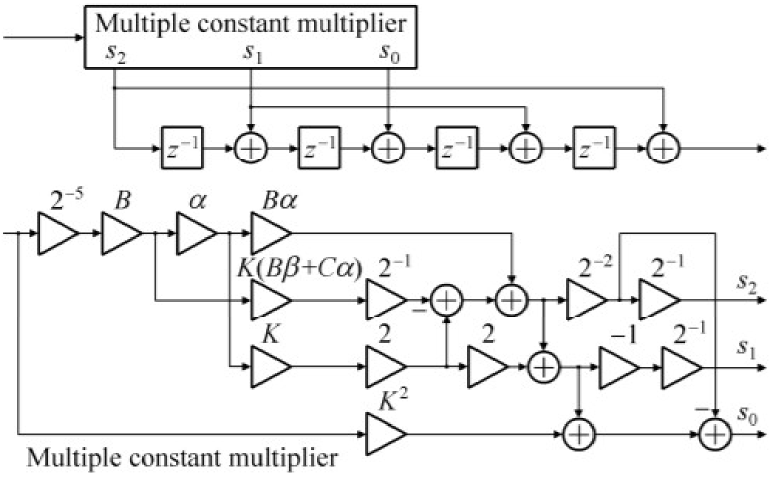

Figure 2: Structure of multiplier-less compensator withfive coefficients for sharpened CIC filter of secondorder.

It is well known that each CSD coefficient contains the minimum number of SPT terms. Consequently, a multiplier with CSD coefficient employs minimum number of adders. However, considering the total number of adders in the compensators, additional savings of adders are possible, resulting in optimum structures described in. Moreover, the optimum structures can also reach the lower bound of total number of adders. Figure 1 and Figure 2 show the structures of the multiplier-less compensators with three and five coefficients that improve the sharpened CIC filter of the second order.

V. CONCLUSION

Performance of CIC (cascaded integrator-comb) decimation filters are studied in this paper. This type of filter has extensive applications in low-cost implementation of interpolators and decimators. With the new structures, the proposed filters can operate at much lower sampling rate. They have advantages in high speed operation and low power consumption.

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