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Design Multiplier-less CIC Filter with Compensators Providing Minimum Passband Attenuation

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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. In this paper, we present a method for the design of simple multiplier-less compensators based on the minimization of the peak-to-peak passband deviation. This type of filter has extensive applications in low-cost implementation of interpolators and decimators. It combines the cascaded integrator-comb (CIC) multirate filter structure with compensation techniques to improve the filter's passband response. Simulation results show the magnitude responses and passband attenuation of the CIC filters, CIC filter with compensator and multiplier-less CIC filter with compensator.
Keywords: Cascaded Integrator-Comb (CIC) filter, decimation, Multiplier-less, Compensator

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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 in two stages 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 as well.

During the last decade, various multipliers-less CIC compensators for improving narrow and wide passbands have been proposed. These compensators are usually realized as single-stage [4] or multi-stage FIR filters. In most applications, they have linear phase response and low number 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 complex structures.

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-channels accomplish examining rate diminish (devastation) and inspecting rate increment (interjection) without utilizing multipliers. A CIC-channel comprises of an equivalent number of phases of perfect integrator and brush channels. Its recurrence reaction might be tuned by choosing the suitable number of fell integrator and brush channel sets. The profoundly symmetric structure of a CIC-channel permits effective usage. The inconvenience of a CIC - channel is that its pass-band isn't level, which is bothersome in numerous 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].

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

$$|H(f)| = \left|\frac{\sin(\pi M f)}{\sin\left(\frac{\pi f}{R}\right)}\right|^N \tag{2}$$

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.

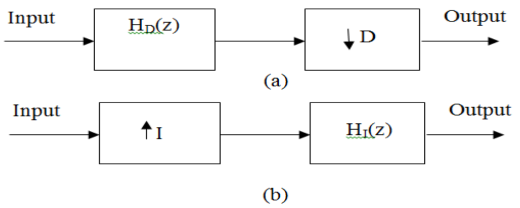

Fig. 1: a) Decimation block diagram b) Interpolation block diagram

Fig. 2 shows the structure of classical CIC filter with K sections. A single section of CIC filter has M zeros and one pole. There is one pole zero cancellation. So, there are M-1 zeros with values $z_s = e^{j.(2\pi/M).s}$, s=1,2,…,M-1. For K stages, total number of zeros is (M-1).K and all zeros are located on the unit circle. So, all zeros are multiples of multiplicity K.

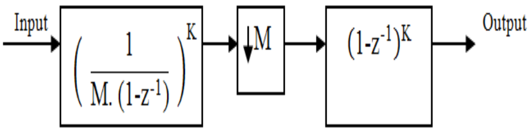

Fig. 2: Simple structure of CIC filter with K sections

III. CIC FILTER WITH COMPENSATOR

To overcome the magnitude droop, a FIR channel that has a size reaction that is the backwards of the CIC channel can be connected to accomplish recurrence reaction adjustment. Such channels are called "remuneration channels."

For information rate down change, the remuneration channel takes after the CIC channel. For up examining frameworks, the remuneration FIR channel pre-conditions the information and is trailed by a CIC channel. At the end of the day, the pay channel dependably works at the lower rate in a rate transformation plan. One advantage of running the pay channel at the low rate is to accomplish a more proficient equipment arrangement, that is, additional time partaking in the pay FIR channel.

$$G(f) = \left| MR\left(\frac{\sin(\pi f/R)}{\sin(\pi Mf)}\right)\right|^N \tag{3}$$

$$\approx \left|\frac{\pi Mf}{\sin(\pi Mf)}\right|^N = \left|\mathrm{sinc}^{-1}(Mf)\right|^N \tag{4}$$

When R is large, the compensation filter response can be approximated by the inverse sinc function, so the compensation filter is sometimes referred to as the “inverse sinc filter.”

IV. PROPOSED METHODOLOGY

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 than about.

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 paper. This compensator performs effective compensation using three additions/subtractions and without using any multipliers.

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

$$\left|G(e^{j\omega M})\right| = \left|1+2^{-d}\sin^2\left(\frac{\omega M}{2}\right)\right| \tag{5}$$

Where d is a suitable integer belonging to set {-2,…,2}, and ω is related to digital frequency f through $\omega = 2\pi f$. By making use of the very well-known identity

$$\sin^2\beta = \frac{1-\cos 2\beta}{2} \tag{6}$$

The corresponding transfer function is of the form

$$G(z^M) = C\left[1+Dz^{-M}+z^{-2M}\right] \tag{7}$$

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

$$C = -2^{-(d+2)} \tag{8}$$

And

$$D = -\left(2^{d+2}+2\right) \tag{9}$$

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

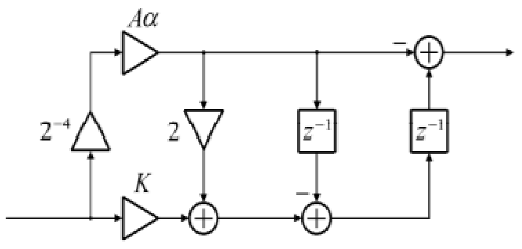

Figure 3: Structure of multiplier-less compensator with three coefficients for sharpened CIC filter of second order.

V. SIMULATION RESULT

Passband attenuation for N=4, K=4 and L=1 of CIC filter, CIC filter with compensator and multiplier-less CIC filter with compensator are shown in Fig. 4. Magnitude response for N=4, K=4 and L=1 of CIC filter with compensator and the multiplier-less CIC filter with compensator are shown in Fig. 5.

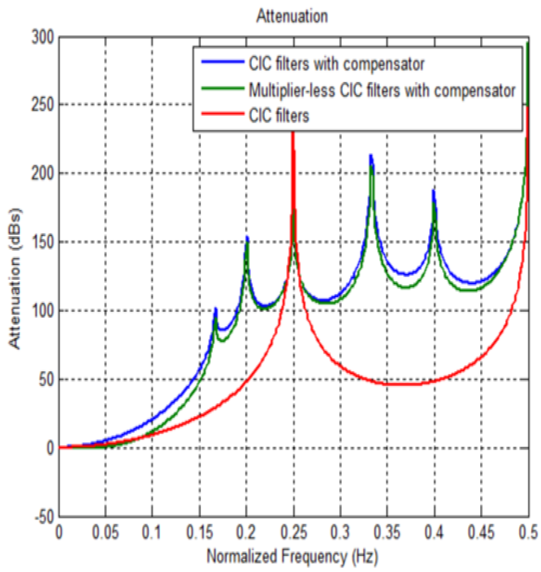

Fig. 4: Passband attenuation of different method of CIC filter for N=4, L=1, K=4

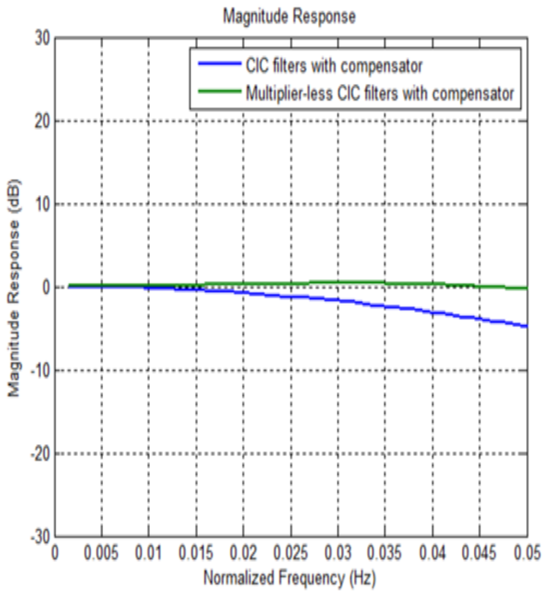

Fig. 5: Magnitude Response of different method of CIC filter for N=4, L=1, K=4

Passband attenuation for N=8, K=8 and L=1 of CIC filter, CIC filter with compensator and multiplier-less CIC filter with compensator are shown in Fig. 6. Magnitude response for N=8, K=8 and L=1 of CIC filter with compensator and the multiplier-less CIC filter with compensator are shown in Fig. 7.

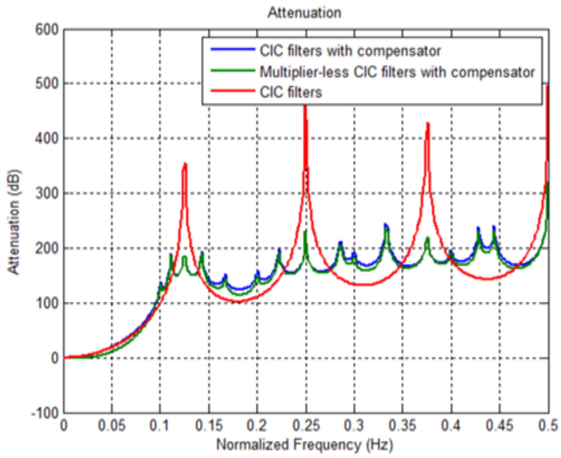

Fig. 6: Passband attenuation of different method of CIC filter for N=8, L=1, K=8

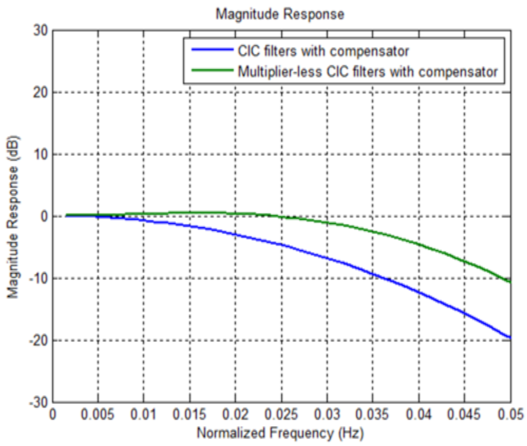

Fig. 7: Magnitude Response of different method of CIC filter for N=8, L=1, K=8

VI. CONCLUSION

The CIC filter is used in many multirate signal processing and communication systems. It presents several advantages over more basic implementations of decimation and interpolation filters: it is a multiplier free; it does not require storage for the filter coefficients; its structure is very regular, it can be designed with only two simple building blocks (differentiator and integrator) and very little external or complicated control is needed. Unfortunately, this filter has two disadvantages: its passband response is not flat and it has less stopband attenuation. The undesired passband droop often leads to use of compensator filters to improve the passband performance.

In order to improve the stopband characteristics of the CIC filter, two novel classes of CIC fir filter functions are introduced in this report, which preserves the CIC filter simplicity by avoiding multipliers. CIC filter with compensation and the designed multiplier-less CIC filter with compensation have the same number K of cascade connections, the same level of constant group delay, as well as number of delay elements, but the novel designed classes gives higher insertion losses in stopband, as well as higher selectivity.

REFRENCES

[1]. Kanika Mehta, C.S. Vinitha and Hemant Tulsani, "A novel class of selective Cascaded Integrator- Comb(CIC) FIR filters with passband compensation", International conference of Digital Signal and Processing, IEEE 2014.
[2]. E. B. Hogenauer, "An economical class of digital filters for decimation and interpolation", IEEE Trans. Acoust., Speech, Signal Process., vol. ASSP-29, no. 2, pp. 155–162, 1981.
[3]. G. Jovanović Doleček and S. K. Mitra, "Simple method for the compensation of CIC decimation filters," Electron. Letter, vol. 44, no. 19, pp. 1162–1163, 2008.
[4]. G. Jovanović Doleček, "Simple wideband CIC compensator," Electron Lett., vol. 45, no. 24, pp. 1270–1272, 2009.
[5]. Fernandez-Vazquez and G. Jovanović Doleček, "maximally flat CIC compensation filter: Design and multiplier-less implementation,' IEEE Trans. Circuits Syst. II, vol. 59, no. 2, pp.113–117, 2012.
[6]. M. Laddomada, "Generalized comb decimator filter for ΣΔ A/D converters: Analysis and design," IEEE Trans. Circuits Syst. I, Reg. Papers, vol. 54, no. 5, pp. 994–1005, May 2007.
[7]. G. Jovanović Doleček, M. Laddomada,"An improved class of multipllierless decimation filters: Analysis and design," Digital Signal Processing 23 (2013) 1773–1782.
[8]. Biljana P. Stošić, Vlastimir D. Pavlović," On design of a novel class of selective CIC FIR filter functions with improved response," Int. J. Electron. Commun. (AEÜ) 68 (2014) 720–729.
[9]. V. D. Pavlović, D. S. Antić, S. S. Nikolić, and S. L. Perić, "Low complexity lowpass linear-phase multiplier-less FIR filter," Electron. Lett., vol. 49, no. 18, pp.1133–1135, 2013.
[10]. Kwentus, Z. Jiang, and A. Willson, Jr., "Application of filter sharpening to cascaded integrator-comb decimation filters," IEEE Transactions on Signal Processing, vol.45, pp.457-467, February 1997.
[11]. G. J. Dolecek, J.D. Carmona, "A new cascaded modified CIC- cosine decimation filter," in: IEEE Conference ISCAS 2005, Kobe, Japan, May 2005, pp. 3733-3736.
[12]. Gordana Jovanovic Dolecek, fred harris, "Design of wideband CIC compensator filter for a digital IF receiver," Digital Signal Processing 19 (2009) 827–837.
[13]. Gordana Jovanovic Dolecek, Massimiliano Laddomada, "A novel two- stage non recursive architecture for the design of generalized comb filters," Digital Signal Processing 22 (2012) 859–868.

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