Power Consumption of CIC Decimation Filter with Sharpened Zero Rotation using VLSI Technique

R.Mononisha[1], G.Brindha[2]

1. P.G Scholar, MuthayammalEngineerinng College, Center for Advance Research, Rasipuram.

2. Assistant Professor, MuthayammalEngineerinng College, Center for Advance Research, Rasipuram.

ABSTRACT

The CIC decimation filter with zero rotation and compensation section was developed and presented in this paper. The magnitude response of the filter with various decimation factors considering different stages were estimated and compared with the existing structures. The sine compensator was used to improve the passband droop and stopband alias rejection. The result showed that the passband droop improvement of 36%, 88%, 89% and stopband improvement of 6%, 7.2%, 2% for the decimation factor 8, 16 and 32 respectively.

Keywords: *CIC filter, Comb filter, Filter sharpening, Zero rotation, Decimator, Compensation filter*

1 INTRODUCTION

The Decimation filter finds wide application in both analog and digital systems for the purpose of data rate conversion as well as filtering. The FIR (Finite Impulse Response) filters have a well-defined frequency response but they require large amount of hardware to store the filter coefficients. The IIR (Infinite Impulse Response) filters are simpler in structure, but they do not satisfy the requirements of linear phase filter which are very much required for obtaining time sensitive features like speech and video. Hence an alternate decimation filter structure which provides better frequency response and consumes fewer coefficients, less power consumption is in high demand. CIC (Cascaded Integrator-Comb) filter structure is one of the filter structure requires less coefficients and which does not have multipliers. Though the hardware requirement is reduced, the frequency response is not improved. This motivated the present research to focus on design of efficient decimation filter structure with less hardware complexity.

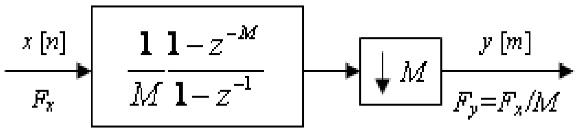
2 CASCADED-INTEGRATOR-COMB FILTER

The CIC filter is a class of hardware efficient linear phase FIR digital filter consists of an equal number of stages of identical integrator and comb filter pairs. The basic concept of CIC filter is given in figure 3.1 (a), which consists of factor of M down sampler and single-stage CIC filter. Applying third identity, the factor of M down sampler is moved and placed behind the integrator section and before the comb section as shown in figure 3.1 (b). Finally the CIC decimator is implemented as a cascade of integrator, factor of M down sampler and the differentiator sections.

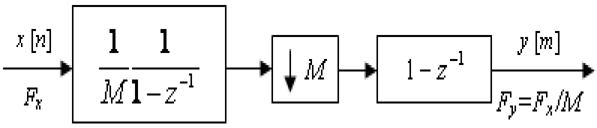
The transfer function of the CIC filter in z-domain is given as

$$H(z) = \frac{1}{M}\left[\frac{1-z^{-M}}{1-z^{-1}}\right] \qquad (1)$$

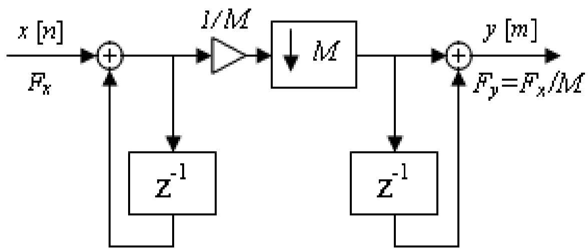
Where, M is the decimation factor



(a) Cascade of CIC Filter and Down Sampler



(b) Cascade of Integrator Section, Down Sampler and Comb Section



(c) Implementation Structure of Single Stage CIC Filter

Fig: 1.1 Block Diagram representation of Single-stage CIC Filter

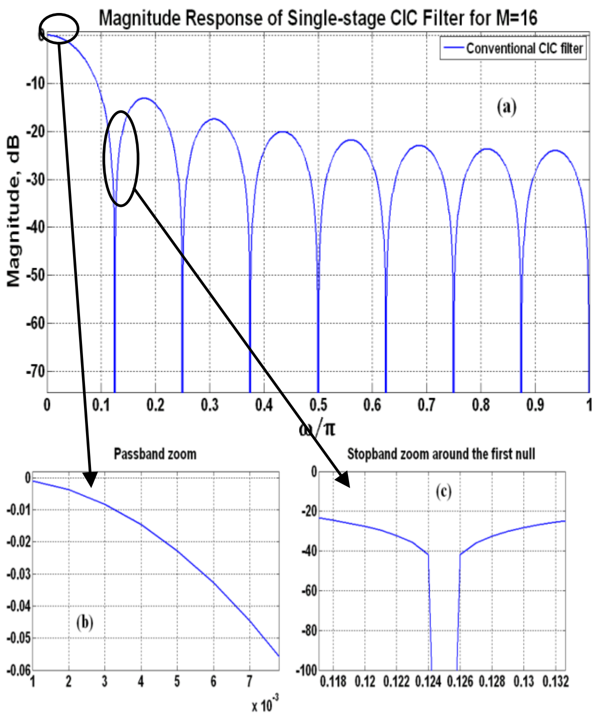


Fig: 1.2 Magnitude response of single-stage CIC filter for M=16 (a) Overall magnitude response (b) Expanded version of Passband zoom and (c) Expanded version of Stopband attenuation around the first null

Figure 1.2 shows the magnitude response of single-stage CIC filter for decimation factor M=16.

3 DESING OF CIC DECIMATION FILTER STRUCTURE WITH ZERO ROTATION AND COMPENSATION

The magnitude response of the CIC filter is improved by cascading several identical CIC filters which is shown in Figure 3.1. The transfer function of the multistage CIC filter composed of K identical single-stage CIC filter is given by

$$H(z)=\left[\frac{1}{M}\frac{1-z^{-M}}{1-z^{-1}}\right]^{K} \quad (2)$$

where, K is the Number of stages

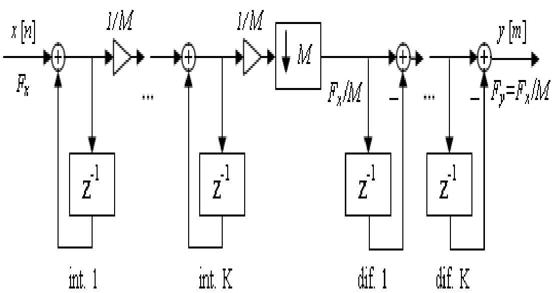


Fig: 3.1 Implementation Structure of multistage CIC Filter

In order to improve the magnitude response of the CIC decimation filter, the CIC decimation filter can be constructed using two sections with different number of stages, resulting in a modified CIC filter as shown in figure 3.2. In modified CIC filter structure, the decimation factor M is divided in to two. ie. $M = M_1 M_2$

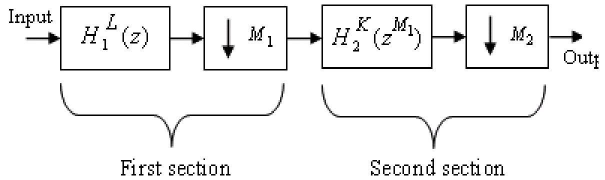


Fig: 3.2 Modified CIC decimation filter

The transfer function of modified CIC filter can be written as

$$H_m(z) = [H_1^{\,L}(z)][H_2^{\,K}(z^{M_1})] \quad L \geq K \tag{3}$$

Where,

$$H_1(z) = \frac{1}{M_1}\left(\frac{1 - z^{-M_1}}{1 - z^{-1}}\right) \tag{4}$$

$$H_2(z^{M_1}) = \frac{1}{M_2}\left(\frac{1 - z^{-M_1 M_2}}{1 - z^{-M_1}}\right) \tag{5}$$

The corresponding magnitude responses are

$$\left|H_1(e^{j\omega})\right| = \left|\frac{1}{M_1}\frac{\sin(\omega M_1/2)}{\sin(\omega/2)}\right| \tag{6}$$

$$\left|H_2(e^{j\omega M_1})\right| = \left|\frac{1}{M_2}\frac{\sin(\omega M_1 M_2/2)}{\sin(\omega M_1/2)}\right| \tag{7}$$

Here $H_1^{\,L}(z)$ and $H_2^{\,K}(z^{M_1})$ are CIC filters, with decimation factor M_1 and M_2 respectively. The first CIC filter section of decimation factor M_1 works at the high input rate and the second section are with decimation factor M_2 which works at the lower rate.

The cascade of single-stage CIC filter results a third-order MCF denoted by MCF_3, whose transfer function as follows

$$H_{MCF3}(z) = H_{CIC}(z) H_{rot}(z) \tag{8}$$

The corresponding magnitude response of third-order MCF_3 CIC filter is given as

$$\left|H_{MCF3}(e^{j\omega})\right| = \left|\frac{1}{M}\left(\frac{\sin(\omega M/2)}{\sin(\omega/2)}\right)\frac{1}{M^2}\left(\frac{\sin[(\pi f - \alpha)M/2]}{\sin[(\pi f - \alpha)/2]}\right)\left(\frac{\sin[(\pi f + \alpha)M/2]}{\sin[(\pi f + \alpha)/2]}\right)\right| \tag{9}$$

Hence the passband droop will depend on the sine compensator and the structure is shown in figure 3.4.

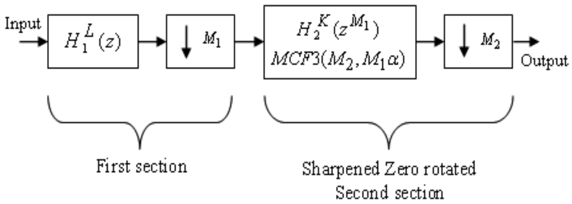


Fig: 3.3 Proposed structure (without compensation)

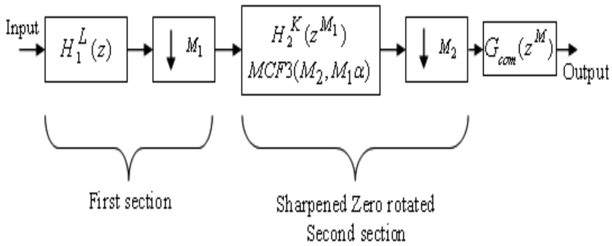


Fig: 3.4 Proposed structure (with compensation)

The compensation filter parameter 'b' depends on the value of K, not on the decimation factor M. For the given value of "b" and K, the values of decimation factors are not expected to affect the worst case alias rejection.

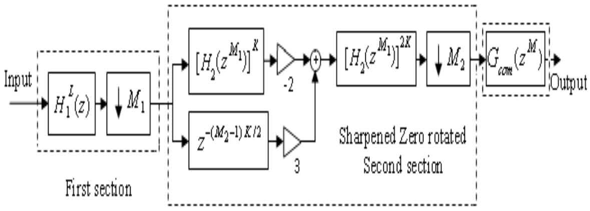


Fig: 3.5 Realization of proposed CIC decimation filter structure with zero rotation and compensation

4 RESULT AND DISCUSSION

The CIC filter with sharpening, zero rotation and compensation is developed and the frequency responses for various decimation factors M=8, M=16 and M=32 are obtained using XILINX. The magnitude responses for different combinations have been computed with and without compensator. The performance of the CIC decimation filter with various parameters considered for analyses are given in table 4.1 is obtained.

Table: 4.1 Parameters considered for analysis

Parameter	Values
Compensation factor, b	6 for *K*=1; 4 for *K*=2; 3 for *K*=4
Filter Quality factor, q	0.78
Maximum signal frequency, f_m	0.02 (Normalized)

The decimation filter with and without compensator is estimated and provided in figure 4.1 for M=8; M_1=4, M_2=2 with (a) K=2 and L=4 and (b) K=4 and L=8.

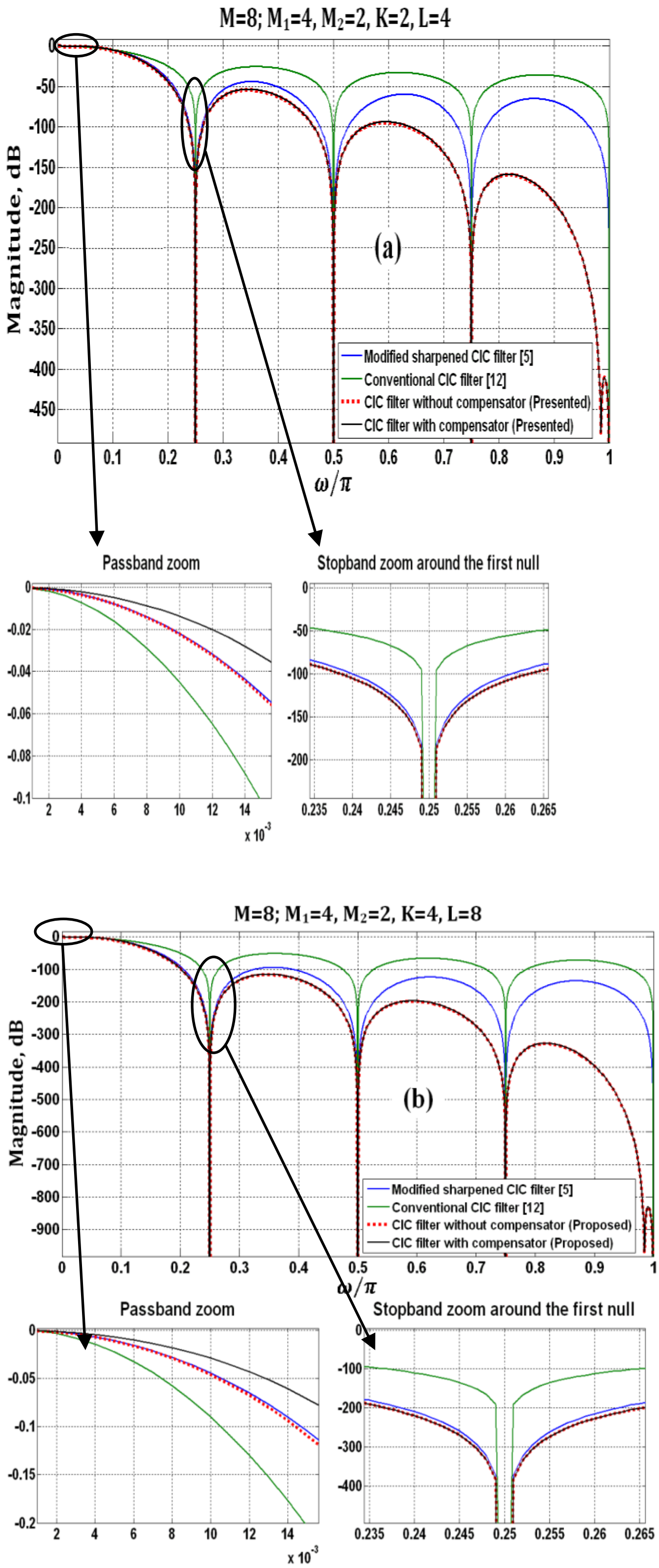


Fig: 4.1 Magnitude responses for M=8; M_1=4, M_2=2 (a) K=2 and L=4 and (b) K=4 and L=8 with Expanded version of Passband zoom and Stopband attenuation around the first null

5 CONCLUSION

The proposed sharpened zero rotated CIC decimation filter was developed. The passband droop and stopband alias rejection were calculated for different decimation factors. The performance of the present and existing filter structures shows that the zeros rotation and compensator improved. It is also found that performance is improved when the decimation factor of first section is greater than the second section ($M_1 \geq M_2$). The developed filter can be used for various wireless applications including WCDMA with decimation factor M=16 and WiMAX with decimation factor M=8.

REFERENCES

1. E. B. Hogenauer, "An economical class of digital filters for decimation and interpolation," IEEE Trans. Acoustic. Speech, Signal Process, vol. ASSP-29, no. 2, pp. 155–162, Apr. 1981.
2. J. F. Kaiser and R. W. Hamming, "Sharpening the response of a symmetric nonrecursive filters by multiple use of the same filter," IEEE Trans. Acoustic. Speech, Signal Process, vol. ASSP-25, no. 3, pp. 415–422, Oct. 1977.
3. Kwentus, Z Jiang, and A.N. Willson, "Application of Filter Sharpening to Cascaded Integrator-Comb Decimation Filters," IEEE Trans. on Signal Processing, vol. 45, no. 2, pp. 457–467, Feb. 1997.
4. L. L. Presti, "Efficient modified-sinc filters for sigma-delta A/D converters," IEEE Trans. Circuits Syst. II, Analog Digit. Signal Process, vol. 47, no. 11, pp. 1204–1213, Nov. 2000.
5. G. J. Dolecek and S. K. Mitra, "A new two-stage sharpened comb decimator," IEEE Trans. On Circuits and Systems, vol. 52, pp. 1414-1420, July 2005.
6. Alfonso Fernandez-Vazquez and G. J. Dolecek, "Maximally Flat CIC Compensation Filter: Design and Multiplierless Implementation," IEEE Transactions on Circuits and Systems-II; Express briefs, vol.59, No.2, pp.113-117, February 2012.