**International Journal of Computer Engineering Science (IJCES)**
Volume 2 Issue 11 (November 2012) ISSN : 2250:3439
https://sites.google.com/site/ijcesjournal http://www.ijces.com/

# DESIGN OF CIC COMPENSATION FILTER FOR DECIMATION FILTER

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**Abstract.** This paper presents the efficient modification in the frequency response of CIC compensation filter. The Compensation filter design consist of FIR filter as cascade after CIC filter. . A FIR filter that has a magnitude response inverse of the CIC filter can be applied to achieve frequency response correction . As proposed filter has only three coefficients so less computation is required. The decimation factor of the CIC filter is M . The performance of the compensation filter depends on the value of a which is obtained by minimizing corresponding error function. Filter coefficient can control the desired pass band droop of the overall decimation filter. The resulting structure is multiplier less and exhibits small pass and droop in comparison to CIC filter. The Cascaded integrator comb filters do not require any multiplier circuits and hence are very economical for implementation in hardware and the problems with cascading faced by the accumulate .A functional model of the CIC compensation filter is developed using the MATLAB program. The paper will describe a mode composed of integrator comb pairs, and it is based on a floating point mathematical algorithm. A series of tests are carried out on this model. Final results show that the CIC compensation filter is a low-pass filter, and its frequency response depends on the number of integrator-comb stages N . As N increases , the CIC compensator has greater stop band attenuation but a less flat pass band. Paper will presented that in the A/D devices no. of analog stages can run at Iower power as

compared to digital stages, they are normally more costly because of a number of manufacturing problems in such component.

**Keywords** : CIC filter, decimation filter, Compensation filter

## 1 Introduction

The cascaded integrated comb filter are a class of hardware efficient linear phase finite impulse response (FIR) digital filters. CIC filters achieve sampling rate decrease (decimation), and sampling rate increase (interpolation) without using multipliers. The CIC filter is used as an anti aliasing filter, when the data rate is high since the operation in the CIC filter only consists of addition operation. The transfer function of the CIC filter can be written as:

$$H(z)=1/R\ ((1-z^{(-R)})/(1-z^{(-1)}))^N$$

where, R and N are the decimation rate and order of the CIC filter.

## 2. CIC COMPENSATION FILTER

CIC Compensation filter Design ,When the number of stages is large, the CIC filter frequency response does not have a wide flat pass band .To overcome the magnitude droop. A FIR filter that has a magnitude response inverse of the CIC filter can be applied to achieve frequency response correction. Implementation structure of the two-stage factor of 10 decimator consisting of the cascade of factor of 5 CIC decimator and factor of 2 FIR decimator. The comb decimators and interpolators are extremely efficient due to their inherent multiplierless implementations.

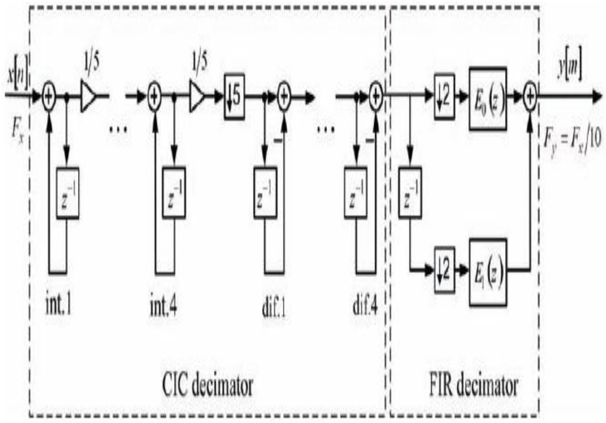



Fig-1 compensation filter

## 3. VARIOUS METHODS USED FOR COMPENSATION OF THE DECIMATION FILTER

3.1 CIC Roll-Off Compensation filter:-

In this method, we compensates the roll off of the CIC filter in pass band by letting the CIC filter followed by a symmetric FIR filter with a minimum order. The coefficients of the compensation filter are given by:-

$$\left[\frac{-a}{1-2a}, \frac{1}{1-2a}, \frac{-a}{1-2a}\right]$$

The performance of the compensation filter depends on the value of a which is obtained by minimizing the corresponding error function.

CIC roll off compensation filter can be written as :-

$$c(n) = \frac{-a}{1-2a}\delta(n+1) + \frac{1}{1-2a}\delta(n) + \frac{-a}{1-2a}\delta(n+1) \qquad 3(a)$$

Where a $\neq$ 0.5 ,

Frequency response C ($\omega$) of the CIC roll off compensation filter C (n) is

$$c(w) = \frac{1-2a\cos w}{1-2a}, \quad a \neq 0.5 \qquad 3(b)$$

Error function are given by :-

$$E_{uw(a)} = \int_0^{P_e} (D(\omega) - c(\omega)f(\omega))^2 d\omega \qquad 3(c)$$

Where $P_e$ is pass band edge of the received signal.

In case of using the weighting function w ($\omega$) the error function is given by :-

$$E_{(a)} = \int_0^{\pi} \left(D(\omega) - c(\omega)f(\omega)\right)^2 W(\omega)d\omega \qquad 3$$

$$a = \frac{\int_0^{\pi} f(\omega)(1-\cos\omega f(\omega))(1-f(\omega))W(\omega)d\omega}{\int_0^{\pi} f(\omega)(1-\cos\omega f(\omega))(1-\cos\omega)W(\omega)d\omega}$$

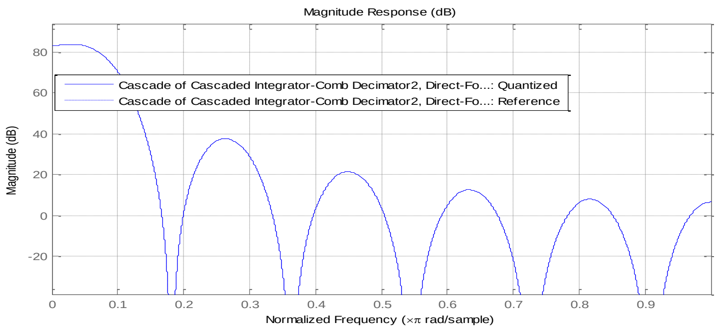



**Fig-1 frequency response of compensation filter**

The respective values of Decimation rate, Output data rate, SNR (dB), a are 2 , 2 times, -37.56dB, 0.1458

It slightly improves of the flatness of the pass band. It requires at least two multipliers and Better compensation in the wideband.

3.2. Compensated CIC-Cosine decimation filter:

Transfer function of compensation filter is given as :-

$$H_{COMP}(Z^m) = a + bz^{-M} + az^{-2M} \qquad 3(e)$$

Where a & b are real valued constant, and M is decimation factor.

Magnitude response is :-

$$|H_{comp}(e^{jM\omega})| = |2\,a\cos(M\omega) + b| \qquad 3(f)$$

Worst pass band distortion occurs at $\omega = 0$ & $\omega = \omega_C$

Where $\omega_C = \frac{\pi}{MR}$ , R is the decimation factor of next decimation stage.

At $\omega = 0$ 2a+b=1 3(g)

In order to compensate the pass band droop δc at the frequency $\omega_c$

$$2\cos(M\omega_C) + b = \frac{1}{\delta_c} \qquad (3h)$$

$$\delta_{comp=}\frac{1}{\delta_z} \qquad 3(i)$$

$$\begin{bmatrix} 2 & 1 \\ 2cos(M(\omega_C) & 1 \end{bmatrix} = \begin{bmatrix} 1 \\ \delta_{comp} \end{bmatrix} \qquad 3(j)$$

$$\begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} \frac{-1}{2(cos(M\omega_C)-1)} & \frac{1}{2cos(M\omega_C)-1)} \\ \frac{cos(M\omega_C)}{(cos(M)\omega_C)-1)} & \frac{-1}{(cos(M\omega_C)-1)} \end{bmatrix} \begin{bmatrix} 1 \\ \delta_{comp} \end{bmatrix} \quad 3(k)$$

$$a = \frac{-1+\delta_{comp}}{2(cos(M\omega_C)-1)} \qquad 3(l)$$

$$b = \frac{cos(M\omega_C)-\delta_{comp}}{cos(M\omega_C-1)} \qquad 3(m)$$

*The respective values of M, K, R are 4, 4, 8*

$$\omega_c = \frac{\pi}{MR} = \frac{\pi}{4\times 8} = 0.9817477$$

$$\delta_{\text{comp}} = \frac{1}{\delta_c} \ \& \ \delta_c < 0.01dB$$

There is a tradeoff between the desired compensation of the pass band droop. Filter coefficient can control the desired passband droop of the overall decimation filter.

3.3 Pass band droop correction:

The transfer function of the proposed compensation filter is given by

$$H_{comp}(z^M) = a + bz^{-M} + az^{-2M}$$

Where a and b are real valued constants and M is a decimation filter. Using multirate identity this filter can be moved to a low rate which is a M times less than high input rate becoming a second order filter .The magnitude response of (3) is expressed as :-

$$\left|H_{comp}(e^{jM\omega})\right| = |2\cos(M\omega) + b|$$

In order to compensate the pass band droop $\delta_c$ at the frequency $\omega_c$

$$\delta_c = \left|\frac{\sin M\pi fn}{M\sin(\pi fn)}\right|^k \quad 3(n)$$

$$\delta_c = \frac{1}{\delta_c} = \left|\frac{M\sin\pi fn}{\sin(\pi fn)}\right| \qquad 3(o)$$

The compensation pass band droop is compared with the generalized magnitude of the CIC filter.

Here, function is used as a normalise frequency term

$$fn = \left(\frac{2fn}{fx}\right)$$

By putting value of δ comp. 3(o) in eq.3(h)

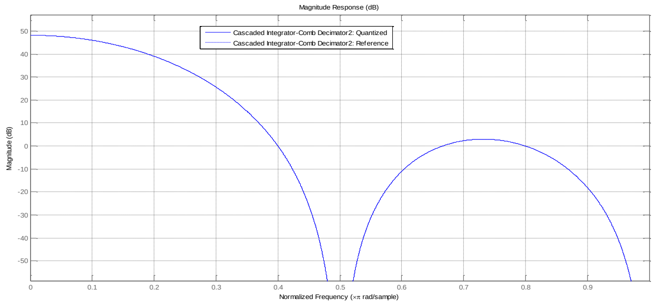
$$2a[\cos(M2\pi fm) - 1] = \delta_{comp} - 1 \qquad 3(p)$$

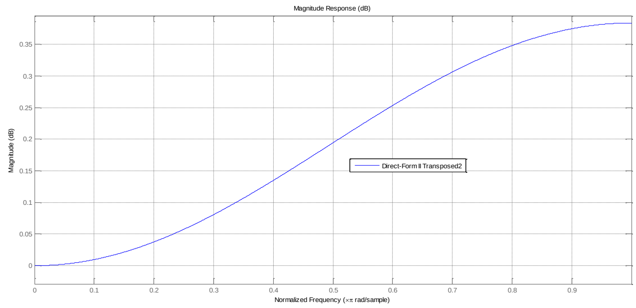
$$a = \frac{\ddot{o}_{comp} - 1}{2[\cos 2\pi Mfm - 1]}$$

b=1-2a

Frequency response of CIC filter is calculated according to the given values

Now using the proposed method coefficients of compensated filter is calculated and frequency response is plotted.






Finally cascading of the CIC filter and compensation filter is made and frequency response is accordingly plotted.

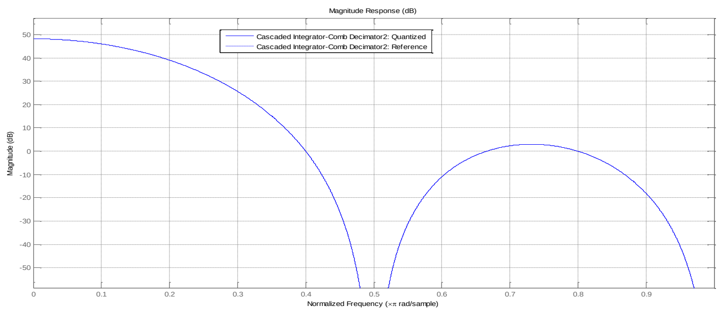



***Figure 3-Response of proposed filter***

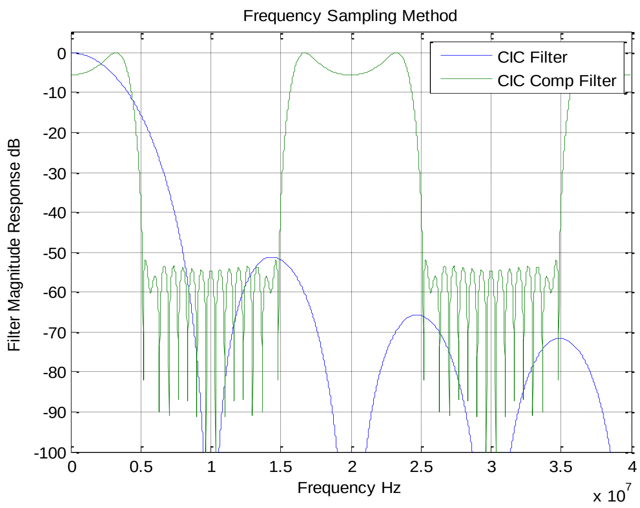



**Figure4- Complete response of CIC compensation filter**

## 4. CONCLUSIONS

This paper presents new CIC compensation filter to compensate for CIC filter that pass band flatness is improve .Here we used three coefficients so less computation is required. The resulting structure is multiplier less and exhibits small pass band droop in comparison to CIC filter.To overcome the magnitude droop.One benefit of the running the compensation filter at the low rate is achieve more efficient hardware solution that is more timing sharing in the compensation filter. The design parameter include M ,K ,and R

## ACKNOWLEDGMENT

The author would like to thank National Institute of Electronics and Information Technology for supporting present this work

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