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Research Article

Implementation of Efficient Multirate Filter Structure for Decimation

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Abstract

In this paper, we proposed the efficient Structure of Multirate filter for decimation process. Now days, decimation is very essential process in many practical applications of digital signal processing. In this case, we introduced three stage decimation filters that performing high decimation process which is generally required in Hearing Aid application, Audio Processing, Noise cancelation and Speech processing. In this paper, implementation of three stage decimation filter is done using the MATLAB Simulink and Xilinx System Generator.

Keywords: *Multirate Digital Signal Processing, Multirate Filter, Decimation, CIC Filter, FIR Filter, MATLAB Simulink and Xilinx System Generator.*

1. Introduction

In many practical application of digital signal processing, there is a problem of changing the sampling rate of a signal, either increasing it or decreasing it by some amount. For example, in telecommunication system that transmits and receives the different types of signals (e.g. fax, speech, video, etc); there is a requirement to process the various signals at the different rates with corresponding bandwidth of the signals. The process of converting a signal from a given rate to a different rate is called as "sampling rate conversion" and the systems that employ multiple sampling rates in the processing of digital signals are called as "multirate digital signal processing system".

2. Multirate Filter

Multirate systems often perform a processing task with improved performance characteristics while simultaneously offering that performance at significantly lower cost than traditional approaches. *Multirate filters* are digital filters that operate with one more sample rate change embedded in the signal processing architecture. Occasionally, the use of a sample rate change in a filtering is the natural consequence of the signal processing chain [Ronald E. Crochiere and Lawrence R. Rabiner et al, 1976]. In other cases, the sample rate change is imposed to access the cost advantages related to multirate processing.

3. Decimation

Decimation can be regarded as the discrete-time counterpart of sampling [Fred harris et al, 2004]. Whereas in sampling we start with a continuous-time signal x(t) and convert it into a sequence of samples $x[n]$, in decimation we start with a discrete-time signal $x[n]$ and convert it into another discrete-time signal $y[n]$, which consists of *sub-samples* of $x[n]$. Thus, the formal definition of M-fold decimation, or down-sampling, is defined by Equation (1). In decimation, the sampling rate is reduced from Fs to Fs/M by discarding M – 1 samples for every M samples in the original sequence.

$$y[n] = v[nM] = \sum_{k=-\infty}^{\infty} h[k]x[nM-k] \qquad \text{........ (1)}$$

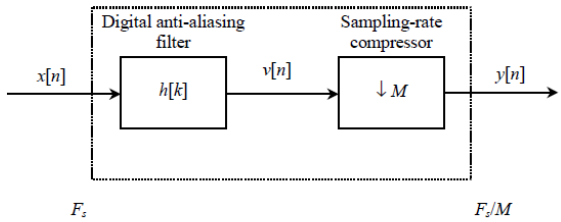

Figure 1: Block diagram notation of decimation, by a factor of M

The block diagram notation of the decimation process is depicted in Figure1. An anti-aliasing digital filter precedes the down-sampler to prevent aliasing from occurring, due to the lower sampling rate. In general, the samples of $x[n]$ corresponding to $n \neq kM$, where k is an integer, are discarded in M-fold decimation [S.K. Mitra et,al, 2003 and Ifeachor and Jervis et al, 2004]. In real time, the decimated signal appears at a slower rate than that of the original signal by a factor of M. If the sampling frequency of $x[n]$ is Fs, then that of $y[n]$ is Fs/M.

4. CIC Filter

In 1981, Hogenauer EB was introduced an efficient way of performing decimation and interpolation [Hogenauer EB

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et al, 1981]. Hogenauer devised a flexible, multiplier-free filter suitable for hardware implementation that can also handle arbitrary and large rate changes. These are known as cascaded integrator-comb Filters or CIC filters.

A CIC filter consists of an equal number of stages of ideal integrator filters 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 in hardware. However, the disadvantage of a CIC filter is that its pass band is not flat, which is undesirable in many applications. Fortunately, this problem can be alleviated by a compensation filter [Vishal Awasthi and Trishla Devi Gupta et al, 2011].

4. FIR Filter

In signal processing, a finite impulse response (FIR) filter is a filter whose impulse response (or response to any finite length input) is of *finite* duration, because it settles to zero in finite time [L. D. Milic and M.D. Lutovac et al, 2002]. This is in contrast to infinite impulse response (IIR) filters, which may have internal feedback and may continue to respond indefinitely (usually decaying).

The impulse response of an Nth-order discrete-time FIR filter (i.e., with a Kronecker delta impulse input) lasts for $N + 1$ samples, and then settles to zero. The non-recursive nature of FIR filter offers the opportunity to create implementation schemes which significantly improve the overall efficiency of the decimator [V.Jayaprakasan and M.Madheswaran et al, 2012].

We have designed and implemented a conventional comb-FIR-FIR decimation filter. FIR filters offer great control over filter shaping and linear phase performance with waveform retention over the pass band.

5. Matlab Simulink

Simulink is a software package for modeling, simulating, and analyzing dynamical systems including in the MATLAB environment. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two Systems can also be multirate, i.e., have different parts that are sampled or updated at different rates. Model analysis tools include linearization and trimming tools, which can be accessed from the MATLAB command line, plus the many tools in MATLAB and its application toolboxes. And because MATLAB and Simulink are integrated, we can simulate, analyze, and revise our models in either environment at any point [Ricardo A. Losada et al, 2008].

6. XILINX System Generator

Xilinx produces many software tools to simplify the design task for hardware programmers. One such program is DSP System Generator. It interfaces with Matlab Simulink and provide efficient implementations of digitally realizable Simulink blocks and commonly used digital programming blocks. Another important feature of System Generator is the Gateway In/out blocks [Suvarna Joshi and Bharati Ainapure et al, 2010]. These provide the interface between the double precision of Simulink with the floating point architecture of FPGA.

7. Block Modeling of Decimation Filter

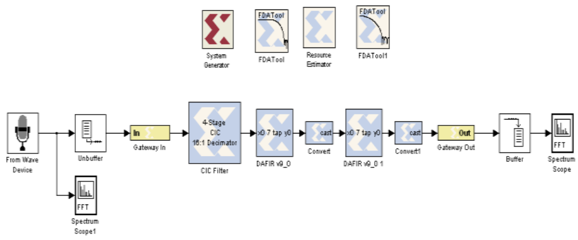

Fig. 2: Three Stage Decimation Filter

This is the Simulink model for three stage decimation filter using Xilinx System Generator used for the audio application. Here we used “From Wave Device” for providing the input high signal rate. This high input signal having frequency 1.28 MHz and this frequency is decimated at about 4 KHz. There is CIC filter which having 4 Stages and having decimation factor is 16. Thus it produced the signal that having frequency 80 KHz. The disadvantage of a CIC filter is that its pass band is not flat, which is undesirable in many applications. Fortunately, this problem can be alleviated by a compensation filter. So that there are used two FIR-FIR filters that offers great control over filter shaping and linear phase performance with waveform retention over the pass band.

First FIR having input sampling frequency of 80 KHz, passband frequency of 20 KHz, a cut-off frequency of 35 KHz and Stop band attenuation is 80 dB. Second FIR filter is a corrector filter which is used in the last stage instead of a shaping filter for less power consumption. This filter having input sampling frequency is 40 KHz with passband of 4 KHz and stopband of 15 KHz.

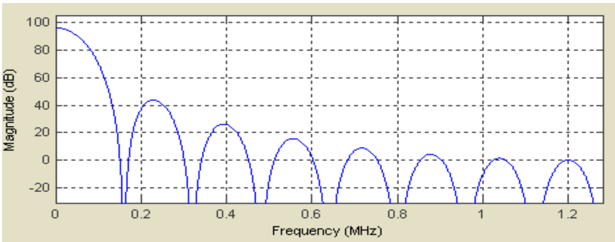

Fig.3: Frequency response of CIC Filter

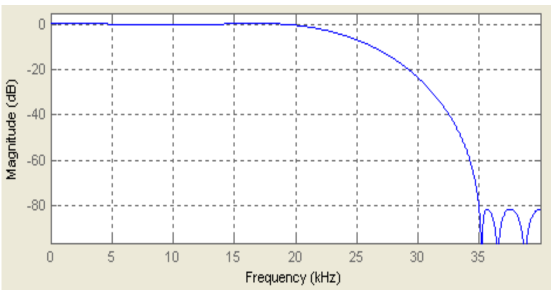

Fig. 4: Frequency response of First FIR Filter

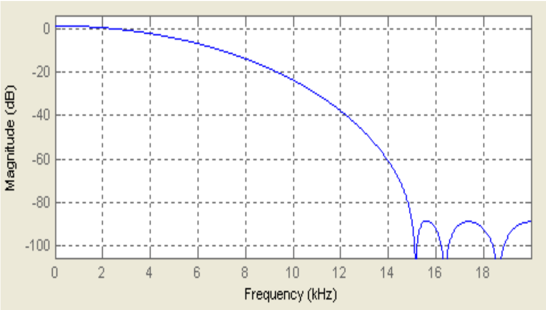

Fig. 5: Frequency response of Second FIR Filter

Conclusion

We are conclude that the proposed design of three stage decimation filter has less power consumption due to the used of Multiplierless CIC filter and also there is no storage required in CIC filter for filter coefficients. Also this design gives the high decimation rate at low power. If we use half band FIR fitters here, there will much reduction in power consumption as compared to proposed design.

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