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Design and Implementation of Digital Chebyshev Type II Filter using XSG for Noise Reduction in ECG Signal

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ABSTRACT
ASIC Chips and Digital Signal Processors are generally used for implementing digital filters. Now days the advanced technologies lead to use of field programmable Gate Array (FPGA) for the implementation of Digital Filters.The present paper deals with Design and Implementation of Digital IIR Chebyshev type II filter using Xilinx System Generator. The Quantization and Overflow are main crucial parameters while designing the filter on FPGA and that need to be consider for getting the stability of the filter. As compare to the conventional DSP the speed of the system is increased by implementation on FPGA. Digital Chebyshev type II filter is initially designed analytically for the desired Specifications and simulated using Simulink in Matlab environment. This paper also proposes the method to implement Digital IIR Chebyshev type II Filter by using XSG platform. The filter has shown good performance for noise removal in ECG
Keywords : XSG, Chebyshev Filter, Noise Reduction, ECG Signal

I. INTRODUCTION

Filters are very important components in digital signal processing when it comes to denoising of the biomedical signals. There are various types of digital filters which can be preferred for this denoising application. Mainly IIR Filters are preferred over FIR filters because of their good performances in terms of various parameters such as speed, area, power etc as it is suggested by lot of authors in various research articles. The digital IIR filters are used for many applications. The most emerging and wide application of IIR filters are used for the suppression of noise in ECG signal. In diagnosis of ECG signal, signal acquisition must be noise free. So the medical communities are able to make correct diagnosis on the condition of heart. IIR filters can be used to remove noise present in ECG signal. Adaptive IIR filters can also be used to control active noise. IIR filters can also be used in Image Processing Applications. IIR filters can be implemented on XSG to enhance the computational speed of filters. The speed of computation is greatly increased by implementing a filter on an FPGA, rather than on a conventional DSP processor. As FPGA is one of the emerged technologies in VLSI which is being used worldwide therefore it can be incorporated with digital filter designs and can be implemented using Xilinx platform so as to obtain good results in terms of said parameters and thus it will help to process various biomedical applications. Various applications and use of digital filters is discussed further by various researchers.

Nidhi Rastogi and Rajesh Mehra have done Analysis of Butterworth and Chebyshev filters for ECG Denoising using wavelets and have proposed a new method for removing the baseline wander interferences, based on discrete wavelet transform and Butterworth/Chebyshev filtering. The ECG data is taken from non-invasive fetal electrocardiogram database, while noise signal is generated and added to the original signal using instructions in MATLAB environment. The proposed method is a hybrid technique, which combines Daubechies wavelet decomposition and different thresholding techniques with Butterworth or Chebyshev filter. DWT has good ability to decompose the signal and wavelet thresholding is good in removing noise from decomposed signal. Filtering is done for improved denoising performence. Here quantitative study of result evaluation has been done between Butterworth and Chebyshev filters based on minimum mean squared error (MSE), higher values of signal to interference ratio and peak signal to noise ratio in MATLAB environment using wavelet and signal processing toolbox. The results proved that the denoised signal using Butterworth filter has a better balance between smoothness and accuracy than the Chebyshev filter.[1] Harshita Pandey and Rajinder Tiwari have proposed an innovative Approach to the reduction of noise in ECG through Chebyshev.The main purpose of this paper is to overcome degradation of this ECG signal by using Chebyshev type 2 digital filters. This paper deals with the design of Chebyshev type 2 digital filter including lowpass, highpass and notch filter.

Reducing noise from the biomedical signal is still a challenging task and rapidly expanding field with a wide range of applications in ECG noise reduction.[2] Seema rani et.al have presented the comparisons of Digital FIR &IIR filter complexity and their performances to remove Baseline noises from the ECG signal hence it is desirable to remove these noises for proper analysis and display of the ECG signal.[3] Sonal Dwivedi have demonstrated three types of IIR (infinite impulse response) filters namely Butterworth, Chebyshev type 1 and elliptic, applying MATLAB software In this paper among all the above types of filter the Chebyshev1, 2 are the best in terms of order and computational or economic purpose. The magnitude responses, phase responses, pole-zero, root locus, step response and impulse response is designed for all type of filters all performed by using MATLAB tool box. It has been found that chebyshev is better in all terms as an average. The output responses prove the better performance of chebyshev with respect to others.[4] This paper represents the review analysis of various types of filters design. In this paper design process of filters is discussed. In this paper for designing of filters various standard papers which are based on filter design were referred.[5] This paper deals with the application of the digital IIR filter on the raw ECG signal. In this paper Butterworth, Chebyshev Type-I and Chebyshev Type-II filter are utilized. At the end all these filter types are compared. In this paper using 222txt ECG data set from MIT-BIH arrhythmia database.[6] This paper introduces the generalized IIR Chebyshev filters. The proposed filters are obtained by applying bilinear transformation to the corresponding analog filters. The novelty of the method is the introduction of a new rational Chebyshev function, which includes Chebyshev Type I and Chebyshev Type II IIR filters as special cases. The application of the proposed digital filters to design perfect reconstruction two-channel filter banks is described. The proposed filters can be applied in orthogonal discrete wavelet transform.[7] Othman et.al have implemented the design of a 100 MHz bandwidth with suitable for 4 channels narrow-band using Chebyshev filter at 5.75 GHz frequency. The design development includes calculation, simulation, measurement and testing. The simulation has been simulated using Ansoft Designer software to determine the bandwidth and the insertion loss, |S21|. The band-pass filter design used Duriod 5880 TLY-5A-0200-CH/CH microstrip substrate parameters and lumped components with Chebyshev passive filter topology. The design is useful for applications in multi-channel narrow-band of wireless communication systems for front-end receiver architecture design. [8] Mahesh S Chavan et.al has introduced the digital filtering method to cope with the noise artifacts in the ECG signal. The Chebyshev I and Chebyshev type II filters are applied on the ECG signal. The detailed design procedure with their responses is depicted in the paper. This article also gives the comparison of both types of the filter. It is found that both digital filters works satisfactory with some limitations. All the designs are implemented using MATLAB FDA tool. ECG data is acquired from the Instrumentation amplifier designed in the Laboratory. For the interfacing of ECG amplifier to the computer advantech 711B add on card has been used. Results of the designed filter are compared with other filters.[9] Mandeep Singh Saini et.al has examined the performance of IIR Chebyshev filters. Higher filter order is disadvantages because the cost of filter is increased and more multipliers are required. But consider a filter of the same order without ripples in the pass band and stop band with the advantage of providing steeper transitions between pass band and stop band. For comparison, Notice the wider transitions that result as a tradeoff. Hence this type of filter plays very important role in spectral analysis of different types of signal. In spectral analysis applications, a small main lobe width of the window function in frequency domain is required for increasing the ability to distinguish two closely spaced frequency components.[10]

Digital Filter Information

The digital filter information is given below, the table 1 describes the detail information of Chebyshev type II filter used for design, table 2 shows filter specifications used during implementation of filter, and whereas table 3 shows implementation cost in terms of number of components such as multipliers and adders used

Filter structure	Direct form II
Number of sections	1
Filter Stability	Stable
Linear Phase	No
Design algorithm	Cheby2

Table 1: IIR Chebyshev Type II Filter Information

Sampling frequency Fs	1000Hz
Filter response	Low pass
Filter order	2
Stopband edge	0.2
Stop band attenuation	80Db
3dB point	0.0029251
6dB Point	0.0038495
Pass band Ripple	1 Db

TABLE 2: FILTER DESIGN SPECIFICATIONS

Number of Multipliers	4
Number of adders	4
Number of states	2
Multiplication per input sample	4
Addition per input sample	4

Table 3: Filter Implementation Cost

Design Scheme

The important information in the ECG signal lies in the frequency range of .05Hz to 100Hz.It is decided to design a low pass IIR Chebyshev type II filter of cutoff frequency 100Hz to remove high frequency noise signal. Chebyshev type II filter gives flat response in the pass band. Sampling frequency used in the design of filter is 1000Hz.

Realization of Filter:

The figure 1 shows design of Chebyshev type II filter using FDA Tool whereas figure 2 shows realization model of the filter.

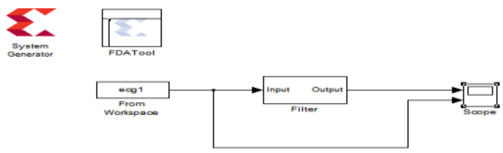


Figure 1: Design of IIR Low pass Chebyshev type II filter using FDA tool

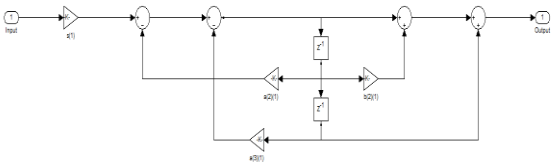


Figure 2 : Realization model of IIR Chebyshev type II filter using FDA Tool.

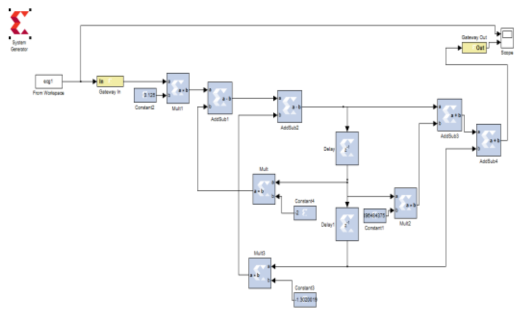


Figure 3: Realization Model of IIR Chebyshev type II filter Using Xilinx System Generator

Implementation Steps

The Digital IIR Chebyshev type II filter can be designed and implemented using following steps. The implementation steps are as follows.

Step 1: Design of low pass Chebyshev type II filter using FDA Tool.

Step 2: Create Simulink Model using Xilinx System Generator.

Step 3: Identify the Filter Coefficients.

Step 4: Complete the simulation model using Xilinx basic elements (XSG block is compulsory)

Step 5: Execute the model ad observe the waveform on Scope.

Step 6: Get Detail summary report which includes the device utilization, Time and power analysis.

Step 7: Get RTL Schematic of the Designed filter.

Filter coefficients

Numerator: 1, -1.3026, 1

Denominator: 1, -1.98700, 0.98708

Gain: - 0.000120

Output Gain: 1

Transfer function:

$$H(z) = -0.000120\left[\frac{(1-1.302z^{-1}+z^{-2})}{1-1.98700z^{-1}+0.98708z^{-2}}\right]$$

Filter Responses

The various responses are depicted in figure 4 to figure 4g. These response shows that designed filter having flat response in pass band and is stable with nonlinear characteristics.

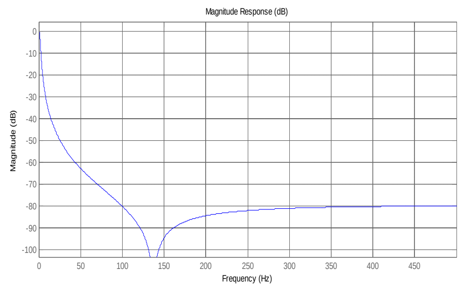


Figure 4: Magnitude Response

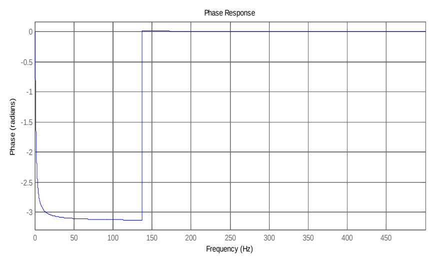


Figure 4a: Phase Response

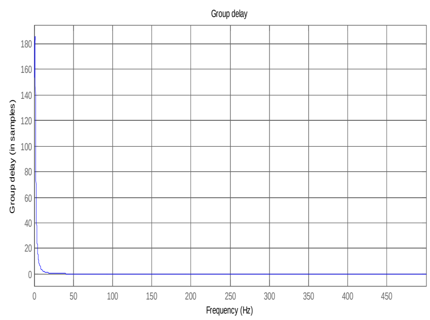


Figure 4b: Group delay Response

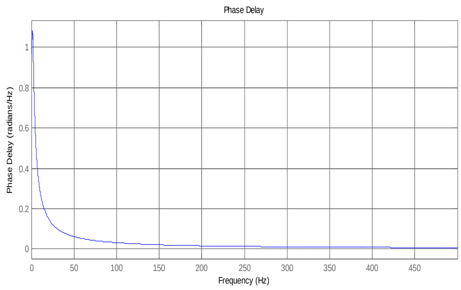


Figure 4c: Phase Delay

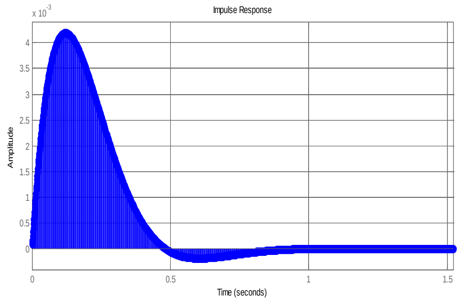


Figure 4d: Impulse Response

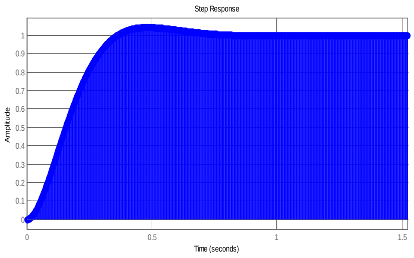


Figure 4e: Step Response

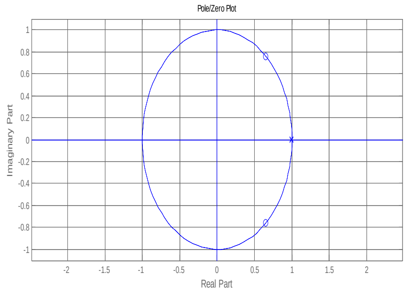


Figure 4f: Pole Zero Plot

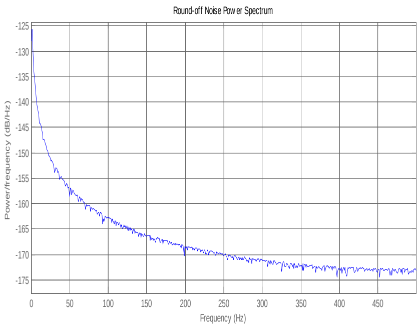


Figure 4g: Round off Noise Power Spectrum

Implementation Results

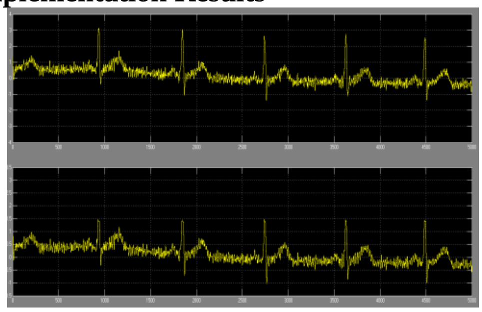


Figure 5: I/P & O/P Waveforms of Chebyshev II filter

Device Utilization Summary

The table 3 shown below gives detail information of the device utilization required for the model. It specifies various parameters like number of LUTs, number. of slices, number of flip-flops etc,this helps to compare the parameters with other types of filter to find out the efficiency of the device.

Configuration File:	iir_normal_chebyshev2lpf_cw.xreport		
Module Name:	iir_normal_chebyshev2lpf_cw		
Target Device:	3s500efg320-4		
Product Version:	ISE 14.2		
Logic Utilization	**Used**	**Available**	**Utilization**
Number of Slice Flip Flops	32	9,312	1%
Number of 4 input LUTs	158	9,312	1%
Number of occupied Slices	145	4,656	3%
Number of Slices containing only related logic	145	145	100%
Number of Slices containing unrelated logic	0	145	0%
Total Number of 4 input LUTs	234	9,312	2%
Number used as logic	158		
Number used as a route-thru	76		
Number of bonded IOBs	33	232	14%
Number of BUFGMUXs	1	24	4%
Number of MULT18X18SIOs	4	20	20%
Average Fanout of Non-Clock Nets	1.63		

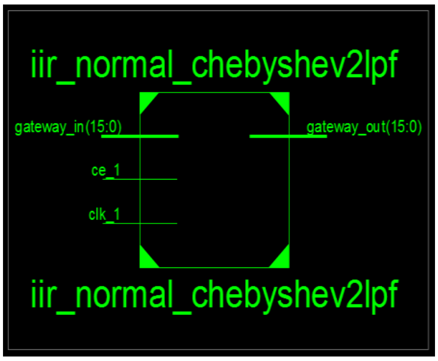
II. TIME & POWER ANALYSIS

The table 4 shown below gives the brief information of the time and power analysis. It shows utilization of the power by different components such as clocks,logic,signals,mults etc

0n –chip	Power (W)	Used	Available	Utilization (%)
Clocks	0.002	1		
Logic	0.003	233	9312	3
Signals	0.005	462		
MULTs	0.001	4	20	20
IOs	0.067	33	232	14
Leakage	0.082			
Total	0.160			

RTL Schematic

The figure 6 shows RTL Schematic of the designed filter after HDL synthesis is executed in the Xilinx Project navagitor tool.



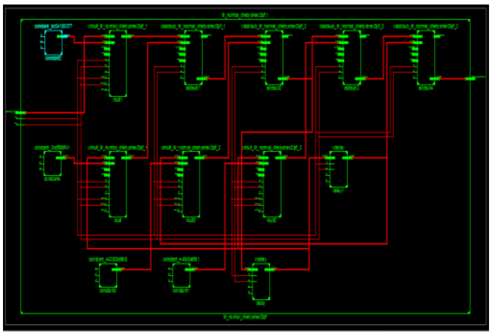


Figure 6: RTL Schematic of digital IIR Chebyshev II Filter

III. CONCLUSION

This paper presents design and implementation of low pass Chebyshev type II filter for noise reduction in ECG signal on XSG platform. Filter is implemented for order 2. Filter has shown good performance considering different parameters such as area, power and Speed when used on FPGA platform. Filter designed have shown good filtering response for reducing high frequency noise from ECG signal. FPGA implementation offers great exposure for implementating different filter designs as it is proven and most used technology in the VLSI world.

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