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Design and Implementation of Low Consumption FIR Bandpass Filters for Matching Biological Data with FPGA

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***Abstract* — Biological Sequences (protein or DNA) are vital in Bioinformatics. These like string adaptation in context of biologics data and a set of protein or DNA sequences are used for discovering evolutionary relationship. In this study we present FIR bandpass digital filter with low power consumption for matching biological sequences. We proposed that instead of using collectors in parallel, design filters so that the collectors will be in series that lead to less power consumption. First the programs of these bandpass filters are designed by MATLAB then MATLAB codes are converted to VHDL by CONVERTOR HDL. Bandpass FIR filter proposed in FPGA ARTIX-7 XC7A100T segment are applied and Synthesized by XILINX ISE 14.2. The power consumption has been analyzed by Xilinx XPower analyzer.**

***Keyword* — Biological Sequences, Matching, DNA, FPGA, FIR bandpass Filter, ARTIX-7 .**

1. INTRODUCTION

Bioinformatics is one of the bioscience field which deals with storage method, recovery and analyzing bio data such as DNA. This process includes of finding gene in DNA sequence of different organism, different methods found for anticipating new protein structure and function and RNA structural sequence and protein Sequence Clustering which related to the family. Genetics informations of any cell are stored in a long molecule called "DESOXY ribonucleic acid" or DNA. DNA is a polymer which is structured from four monomers. DNA is a long sequence of Nucleotide base pairs which is summarized in a character string with "A,C,G,T" alphabet. A is the abbreviation of Adenine, C is the abbreviation of Cytosine, G (Guanine) and T (Thymine). In this way scientist used these four alphabets for showing DNA molecule. They called this long sting "sequence". In fig. 1, DNA and RNA are been shown. The different between these two is that DNA has two twisted helix but RNA has one.

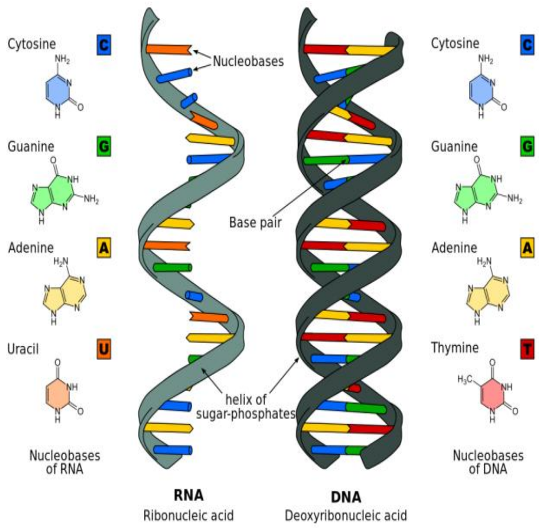

Fig.1. Figure DNA and RNA [1]

Scientists use a new founded sequence from previously known set of sequence for figuring out the bio information. For example, if a discovered sequence is like a known illness gene, the bio information for function of new sequence could be inferred. This is very significant in early diagnosis. Moreover, biological sequence has important role in studying of evolutionary development and species history. Programmable Gate array technology (FPGA) is better hardware solution for molecule and protein structure because of its process rate and velocity. In study 4 the implementation of Aho Corasick in FPGA is proposed by alphabet and Peptides in order to make Finite state machine. In this study, the Parallel hardware architecture has been used for adapting DNA based on BLAST algorithm steps. A new parametrized model of architecture has been designed for approximate Detecting tandem repeat and another method with FPGA technology has been proposed for automatic writing of it [6]. In study [7], the accelerator has been proposed again for adapting words from BLASTN algorithm by BLASTN. This word adaptation stage is divided to three sub-stages, as you see in fig. 2. The first sub-stage is a Bloom parallel filter, second sub-stage is false positive elimination for reviewing crossing filter data, and the last is elimination of adaptation.

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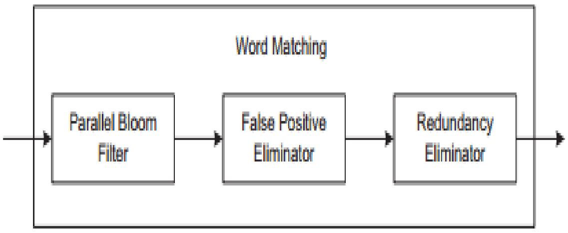

Fig.2. Tuesday substages of FPGA-based accelerator for the matching word BLASTN [7]

Biological sequences have an algorithm that if implement in hardware will be very useful. FIR filters is one of the blocks that are used in implementing bio sequence in hardware. FIR digital filter are used in most of the digital signal processing program. Parallel process could be applied in FIR digital filters in order to lower consumption of main filter. Traditionally, using parallel process in a FIR filter includes of repeating hardware unit which are exist in main filters [8]. One of the FIR filter implementation is using of applied collectors and connected shifts [9]. These are used a common change in the elimination algorithm of expression for decreasing some of the collector. In [10] a new method is recommended for designing a method by low consumption digital band. Their method is to optimize bit width from coefficient of each filter. They define the problem of optimized band width from coefficient of each filter. In study [11] writers try to propose a FIR filter that capable of programming which has low consumption. Asymptomatic multipliers are used for implementing these filters and function rate of switching is decreased. The rest of this article is as following: section 2 is FIR filter theory, section 3 is architecture platform, section 4 is design of FIR filter and section 5 is conclusion.

2. FIR Filter Theory

Digital filters are used widely for indentifying system, adjustors, noise elimination, dialogue signal code and etc. these filters increase date sending rate and decrease circuit volume. General equation of digital filter are as following (1):

$$Y(n) = -\sum_{K=1}^{N} ak\, y(n-k) + \sum_{K=0}^{M} bk\, x(n-k) \qquad (1)$$

Two states of equation in IIR and FIR are:

- Finite impulse response filter; without feedback: [ak]=0
- Finite impulse response filter: with feedback: : [ak] $\neq$0

A FIR system with example response is a unit with limited length, in other words output in this system is a combination of current input and M of previous input example. So output of FIR system in terms of input example is as following:

$$Y(n) = b0\, x(n) + b1x(n-1)+\ldots+bM\, x(n-M)$$

$$Y(n) = \sum_{r=0}^{M} x(n-r) br \qquad (2)$$

If br in above equation substitutes with h(n) we have:

$$Y(n) = \sum_{r=0}^{M} x(n-r) h(r) \qquad (3)$$

In this matters a FIR filter of M degree are defined by multiple M+1.

Equation 2 is a convolution between X(n) and h(n). If conversion equation 1 parties are premised Z, conversion function of FIR system is:

$$H(z) = \sum_{r=0}^{M} h(r)\ z\text{-}r = \sum_{r=0}^{M} br\ z\text{-}r \qquad (4)$$

If z substitute with ejw, frequency response of FIR system will be obtained.

$$H(e^{jw}) = \sum_{r=0}^{M} br\ e^{-jwr} \qquad (5)$$

In FIR, output signals of filter adjusted after input signal of zero to non zero, non zero could be premised in limited number. FIR filter are always stable. FIR filters are limited which is a necessary feature for linear phase.

The most common digital filter is linear time-invariant filter. LTI digital filter is generally is classified as Finite impulse response (for example FIR) or infinite impulse response. As it convey from their names, a FIR filter includes of Finite number of sample values, reduction of top convolution to infinite sum in output example. FIR with constant coefficient of a digital filter is LTI. FIR outputs in terms of priority or L length are a input time series X[N] which are given by a Limited Edition of convolution in (6): in means:

$$y[n] = x[n] * f[n] = \sum_{K=0}^{L-1} f[K]\, X[n-K] \qquad (6)$$

F [0] $\neq$ 0 is filtered by F [L - 1] $\neq$ 0 which is L. these are matched with FIR Impulse response. Z impression sometimes are easier for LTI systems.

$$Y(Z) = F(Z)\, X(Z) \qquad (7)$$

In which F(z) function is transfer function impressed in Z domain :

$$F(Z) = \sum_{K=0} F[Z]\ Z^{-K} \qquad (8)$$

3. Technology Artix-7

If you are using In this article we presented a succinct introduction about applied technology in FPGA ARTIX-7. Newest generation of series 7 machine is created in 28nm process technology which has the lowest cost and consumption of FPGA in products such as portable medical equipment, army radio and compact wireless infrastructure. The total power consumption are 50% lesser than previous generation. Also FPGA ARTIX-7 family have other advantage which we present in following [12]:

- The best performance for DD3, DSP, parallel and I/O serial
- 930 GMACs process of DSP for high quality image and optimize RF signal
- Small form Factor for devices as size as laptop and tablet
- Over 50,000 logical cells in a 10*10 mm package
- Integrated Memory Interface for easy access to video and data
- New hard IP blocks for decreasing development time
- 23 MicroBlaze processor for controlling real time of industrial handling tasks Ethernet from main CPU

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4. Implementation Filter FIR

4.1 FIR band-pass filter implemented in MATLAB

Design of filter means making the filter coefficients so that meet some filtering essentials. Implementation of filter means choosing and applying of a special filter structure on these coefficients. Just after designing and implementation we could filter the data. There are different methods for designing FIR filters. In table (1) order used for FIR filter designing is shown in different way.

Table (1) Commands used to design FIR filters to different methods

Filter design methods	**Description**	**Instructions for use**
Windowing	Applying the inverse Fourier transform filter is ideal for cutting window	Firl1,firl2, kaiserord
Multiband with Transition Bands	Method of least squares on the band frequency range	Firls,firpm, firpmord
Constrained Least Squares	Minimization sum of squared errors over the entire frequency range in order to bound the maximum error	Firels, fircls1
Arbitrary Response	The desired response, including nonlinear phase and mixed responses	Cfirpm
Raised Cosine	Low-pass response with smooth sinusoidal response	Firrcos

Our desired filter is FIR bandpass filter which its code is written in MATLAB.

```
clc
clear
close all
Fs=50000000;
Ap=1;
As=45;
M=[0 1 0];
F=[10000000, 12000000, 16000000, 18000000] ;
dp=(10^(Ap/20)-1)/(10^(Ap/20)+1);
 ds=10^(-As/20);
 dev=[ds dp ds];
 [N1, F0, M0, W] = remezord(F, M, dev, Fs);
 [b delta] = remez(N1, F0, M0, W);
 [H, f] = freqz(b, 1, 1024, Fs);
 mag = 20*log10(abs(H));
 plot(f, mag),
 grid on
 xlabel('Frequency (Hz)')
 ylabel('Magnitude (Db)')
```

Fig. 3, is designed FIR filter in MATLAB which limited in 1 to 1.8 MH frequencies.

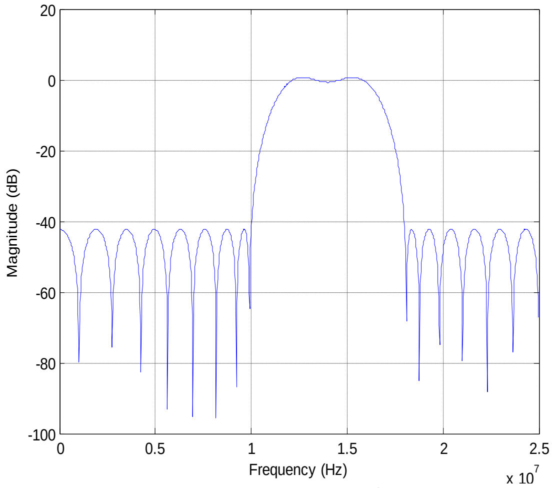

Fig. 3 . FIR bandpass filter

4.2 FIR filter design with FPGA

In this article we converted code that is written in MATLAB by convertor hdl to vhdl in order to filter FIR bandpass. Then VHDL code is applied on FPGA ARTIX-7 XC7A100T unit by XILINX ISE 14.2 software. Bandpass FIR filter has a fir-4tp main core which is shown in fig. 4. This main core is included of three DFF1, DDF2 and DDF3 program.

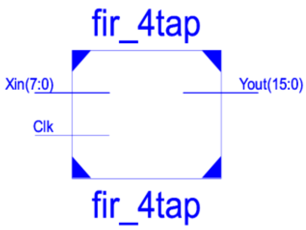

Fig. 4 . Block diagram FIR bandpass filter

In fig. 5 and 6 respectively you see RTL schematic and designed FIR bandpass technology which are obtained by ISE 14.2 software. As you see in RTL schematic three DPS processor are included.

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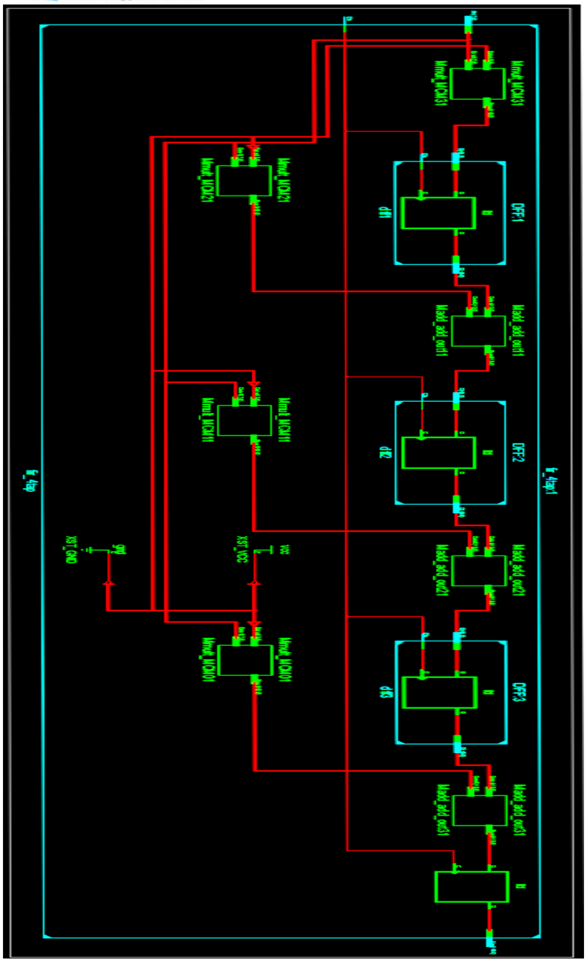

Fig. 5 . RTL schematic FIR bandpass filter

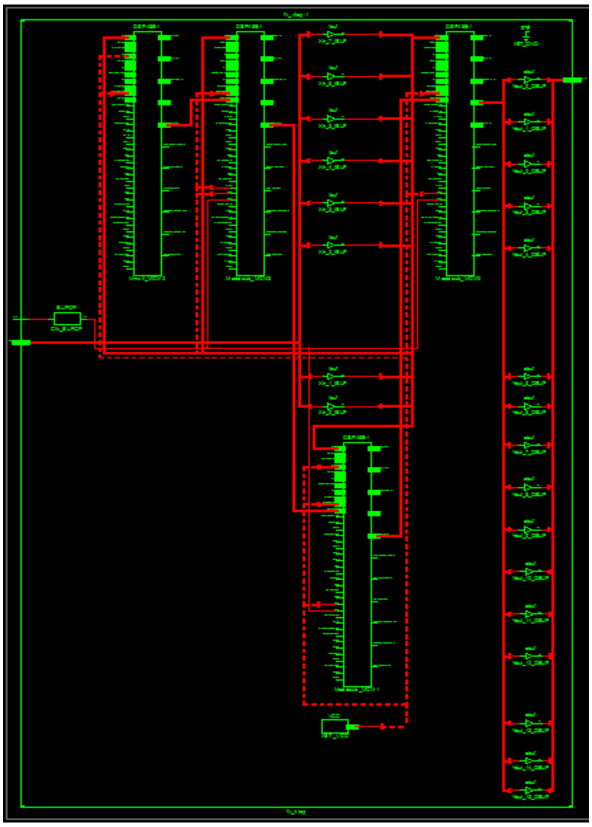

Fig. 6 . Schematic technology band-pass filter FIR

In fig. 7 layout FIR filter is designed.

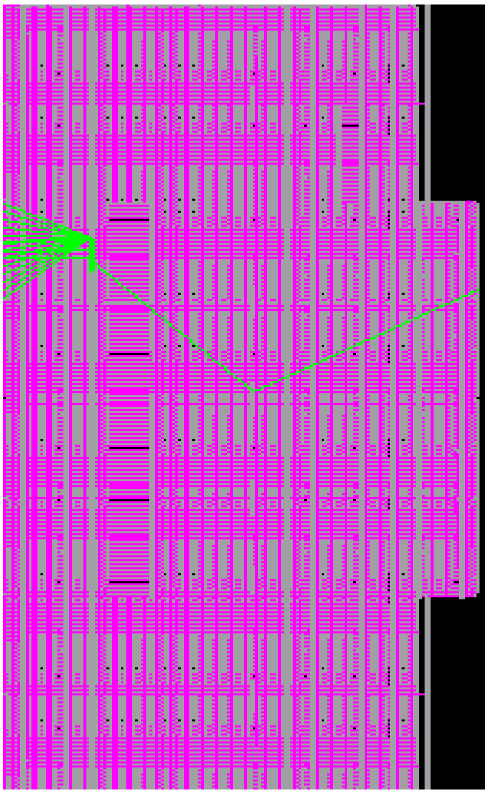

Fig. 7 . layout filter fir designed

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In table (2) the results of output FIR digital band-pass filter are presented which includes of numbers of block and the other used factor for filter design.

Table (2) The results of the FIR filter designed

Slice Logic Utilization	Used	Available
Number of bonded	25	210
Number of BUFG/BUFGCTRLs	1	32
Number of DSP48E1s	4	240

In fig. 8, the wave of output and input of FIR bandpass filter are designed. The shape of the wave is drawn by ISE 14.2 software.

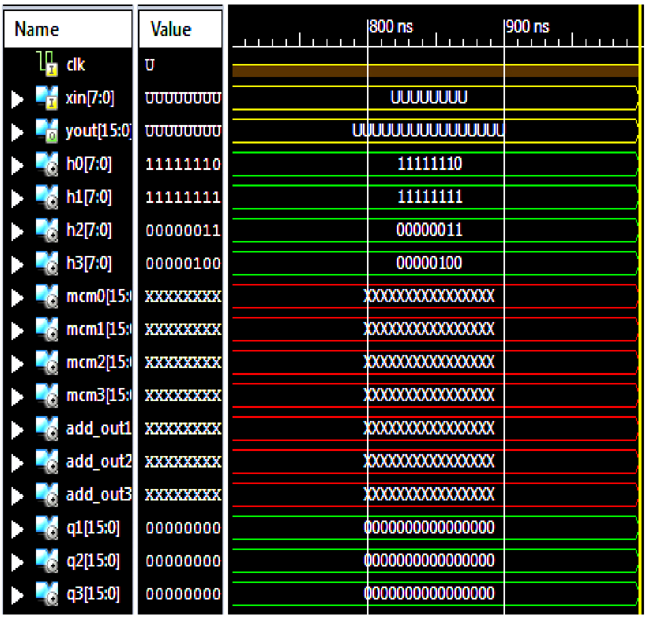

Fig. 8 . FIR bandpass filter waveforms

Also in this article the power of filters are shown. In table (3), the power are obtained in 3 frequencies.

Table (3) power obtained by bandpass filter FIR

Frequency	25 MHZ	50 MHZ	75 MHZ	100 MHZ
Power obtained	123 mW	155 mW	186 mW	220 mW

5. Conclusion

In this article we designed a low consumption FIR bandpass filter for Maching biological data. Biological Sequences include of DNA data which are designed by digital filters and could be adapted to DNA information. We proposed that instead of using collectors in parallel, design filters so that the collectors will be in series that lead to less power consumption.. Proposed FIR bandpass filter are implemented by FPGA ARTIX-7 XC7A100T and power consumption is analyzed by Xilinx XPower analyzer. The results of Proposed filter stimulation with low consumption was favorable.

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