ECG Verisi İçin Alanda Programlanabilir Kapı Dizileri ve MATLAB Tabanlı Dijital Filtre Tasarımı ve Gerçeklemesi

Design and Implementation of Digital Filters for ECG Data Based on Field Programmable Gate Array and MATLAB

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***Özetçe*—Bu çalışma, seri haberleşme yoluyla EKG (elektrokardiyografi) verileri için MATLAB™ ve FPGA kullanılarak dört dijital filtre (alçak geçiren, yüksek geçiren, bant geçiren, bant durdurma) tasarımını ve gerçekleşmesini sunar. Çalışma PhysioBank Veri Tabanı platformundan elde edilen EKG verileri kullanılarak gerçekleştirilmiştir. MATLAB™ için bir araç kutusu olan SysGen (System Generator for DSP™) dijital filtreleri tasarlamak ve uygulamak için kullanılır. Çalışmanın amacı, SysGen araç kutusunda çeşitli bloklar kullanılarak dört farklı dijital filtre gerçekleştirmektir. Çalışma daha sonra dört farklı dijital filtrenin sonuçlarını inceler.**

Anahtar Kelimeler—EKG, Filtre, FPGA, MATLAB

***Abstract*—This study provides design and implementation of four digital filters (low pass, high pass, band pass and band stop) for ECG (electrocardiogram) data on FPGA with MATLAB™ by a serial communication. The study is conducted with using ECG data which is obtained from PhysioBank Database platform. SysGen (System Generator for DSP™) which is a toolbox for MATLAB™ is used for designing and implementing the digital filters. The aim of the study is to perform four different digital filters with various blocks on the SysGen Toolbox. The study then examines the results of four different digital filters.**

Keywords—ECG, Filter, FPGA, MATLAB

I. INTRODUCTION

The electrocardiogram (ECG) is the recording of electrical potential with time that belongs to heart [1]. That signal may be corrupted with noises such as environmental and biological resources. Today, microprocessor-based signal recorders have been developed that works with signal processing and data reduction [2]. Computational power of the microprocessor allows to implement digital filters for noise cancellation and arrhythmia (problem with the rate of heartbeat) detection [3]. For example, Lynn [4], [5] and Didier and Thakor have developed digital filters which has quantized coefficients for real-time processing with microprocessors.

Digital filters operate on the signal as linear system to cancel noise effect. They can be used either in software or hardware. Hardware implementation can be conducted in real-time by a DSP processor [6]. On the side, software implementation can be performed with efficient algorithms as a digital filter using DSP software toolbox such as Xilinx SysGen for DSP toolbox [7].

In this paper, the aim is to remove ECG noises such as respiratory signal and body movements which cause problems during ECG arrhythmia detection and processes of some classification. This process carries out by using digital filters such as high pass, low pass, band pass and stop band.

II. METHODS AND MATERIALS

A. Field Programmable Gate Array and System Generator Toolbox

Field Programmable Gate Array (FPGA) are the digital integrated circuits with programmable logic blocks, interconnections between blocks, and many uses. It is designed for the purpose of realizing the logic circuits and functions that the programmer needs to use in the project. Therefore, the function of each logic can be regulated by the

programmer. The FPGA consists of three main parts, which can be arranged as programmable logic blocks, input-output blocks surrounding the block array, and interconnections.

The typical FPGA logic block consists of four input Look Up Table (LUT) structure and other logic elements such as flip-flops. LUT structure with four inputs executes various logical operations.

Figure 1. Spartan-3E Board [8]

Two methods which is namely graphical design and HDL are used to program the FPGA. In graphical design, the design is done using tools and logic gates in the library of the compiler program. Very High-Speed Integrated Circuit Hardware Description Language (VHDL) and Verilog are most widely used HDL types. In this study, Spartan-3E 250 CP132 model FPGA, VHDL programming language and System Generator (SysGen) are used in order to make system work properly.

SysGen for DSP™ is the industry's leading architecture-level design tool to define, test and implement high-performance DSP algorithms on Xilinx devices. SysGen is designed as an add-on toolbox for Simulink platform of the MATLAB. Generator for DSP features combined with the advantages of an upscale simulation and verification environment offered by Simulink enables the creation of production-quality DSP algorithms.

B. Digital Filters

A digital filter is a method or algorithm that operates on digitized analog signals, converting the input signal into the desired output signal. The main design objectives of the very wide range of filters are to distinguish between mixed signals, to reduce signal noise, to improve signal quality, and to recover distorted signals.

A combination of different types of filter such as low-pass, high-pass, band-pass and band-stop filters have been developed for noise reduction from ECG signals in many applications.

The most reliable and easy way to implement those filters is the pole-zero placement method. This method suggests that placing zeros to the frequency component that is considered unwanted and placing poles to the frequency component that is desired to obtained. The place of the poles and zeros describes the different filter types as mentioned before.

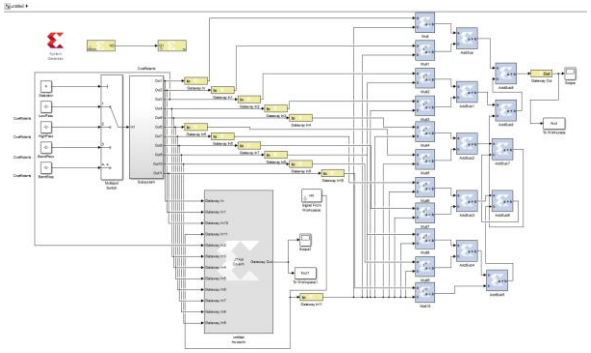

Figure 2. SysGen Block Design

In this study, firstly four different filters which are low-pass, high-pass, band-pass and band-stop are designed with MATLAB environment according to the ECG signal and Fourier Transform of ECG signal (Figure-3,4) figure to ensure that the designed filters operate correctly. Then, the designed filters are built in System Generator Toolbox (SysGen) environment with adder, multiplier and delay blocks (Figure-2). The pole-zero placement of four different filters that are designed in MATLAB is shown in Figure-5.

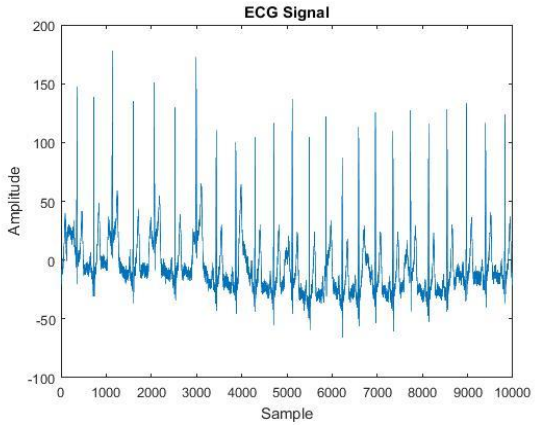

Figure 3. Original ECG Signal [9]

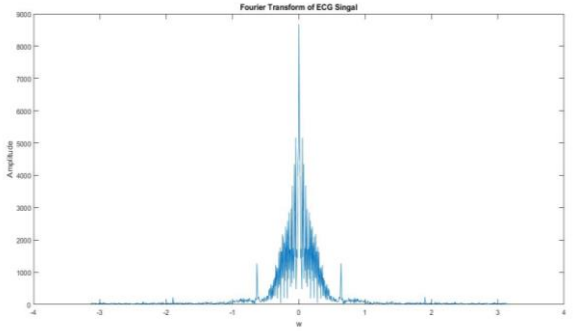

Figure 4. Fourier Transform of ECG Signal

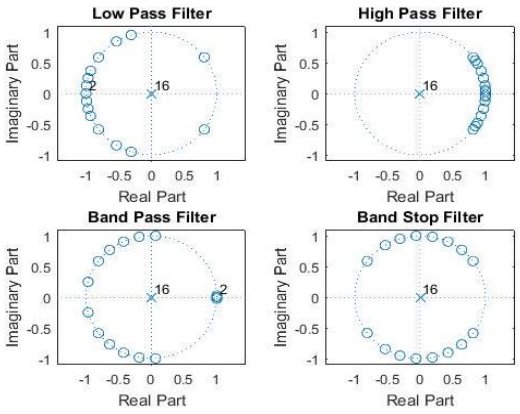

Figure 5. Pole-Zero Map of Designed Filters

III. EXPERIMENTAL RESULTS

In order to evaluate the designed digital filters several experiments were performed using recorded data that is obtained from the database platform known as PhysioBank [9]. Experimental results for noise reduction using four different digital filters are presented in following figure (Figure 6). The figure shows that the heartbeat data with noise are successfully filtered with low pass, high-pass, band-pass and band-stop digital filters.

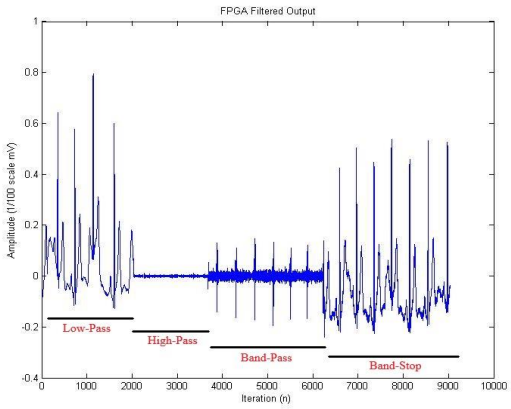

Figure 6. FPGA Filtered Output

IV. CONCLUSION

In this study, design and implementation of four different digital filters which are low pass, high pass, band pass, and band stop on ECG data are performed with the MATLAB ™ and Field Programmable Gate Array (FPGA) environments. At the first stage, the design and test of the filters are conducted in the MATLAB environment. At the second stage, by using various blocks on the SysGen environment the four digital filters are created and tested. The results show that the filters are successful to filter out the noisy ECG data.

AUTHOR CONTRIBUTIONS

Each author contributed equally to this study.

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