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IMPLEMENTATION OF ADAPTIVE FILTER USING SIMULINK ON FPGA FOR THE ENHANCEMENT OF T-WAVES IN A MULTILEAD ECG

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ABSTRACT

Now a days, T-waves Alternans (TWA) are being studied rigorously for the detection of Sudden Cardiac Death (SCD) due to Myocardial Arrhythmia. TWA is a cardiac phenomenon that appears in the electrocardiogram (ECG). The major challenge is detection of small variations (approximately 1μV) in T-waves that too in the presence of various noise artifacts like power line interference, DC drift, EMC contraction, electronic noise and other noise from muscle artifacts. Therefore the accurate detection of T-waves play an important role in the detection of SCD. In this work, we design and implement an Adaptive filter that accepts a multilead (atleast 2) ECG and enhances the T-wave portion of ECG. The output of this filter is further analysed for its spectrum to detect T-wave alternans.

KEYWORDS : MATLAB Simulink®, Xilinx ISE 14.2, Spartan 3E Starter Kit, ECG

I. INTRODUCTION

The cardiovascular diseases (CVDs) are still the major cause of death globally; most of the deaths around the world are due to CVDs compared to any other reason. 37% deaths among 16 million are happening due to CVDs. CVDs are a group of abnormalities of the heart and blood vessels and includes coronary heart disease (heart attacks), cerebrovascular malady (stroke), raised pulse (hypertension), fringe conduit infection, rheumatic coronary illness, intrinsic coronary illness and heart disappointment. The major causes of cardiovascular disease are tobacco use, physical inactivity, an unhealthy diet and harmful use of alcohol.

The electrocardiogram (ECG) is the recording (gram) of the electrical activity (electro) generated by the cells of the heart (cardio) that reaches the body surface. ECG provides very important and time-critical information related to cardiac function, cardiac health and cardiac pathology [1]. The frequency range of an ECG signal is of 0.05-100 Hz and has a dynamic range of 1-10 mV. The ECG sign is described by five crests and valleys named by the letters P, Q, R, S, T as indicated in Fig.1. In some cases (especially in infants) we may also find another peak called U.

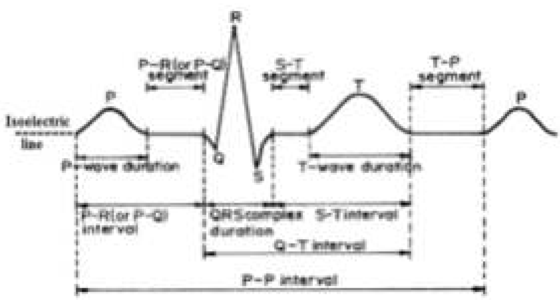

Fig.1. Normal ECG signal

II. EXISTING METHOD

The earlier method of ECG is with respect to the time domain which is insufficient to learn about all the features. So, there is a need to develop a frequency representation of the signal. But, this technique has a negative aspect in yielding data regarding the exact position of frequency components in time. In order to get the exact location, time frequency representation can be developed. Also this method is neither immune to noise nor cost effective with lack of satisfactory performance and the ECG signals are of poor quality. To overcome the above problems, an adaptive filter with FPGA is used.

III. PROPOSED METHOD

This work is different from the previous versions in the usage of an Adaptive Filter instead of a Static one. Also, the DSP processor is replaced with an FPGA. Here we develop an Adaptive filter over onboard ADC and DAC of Spartan 3E FPGA [5]. The block diagram describing our process is as shown below in Fig.2

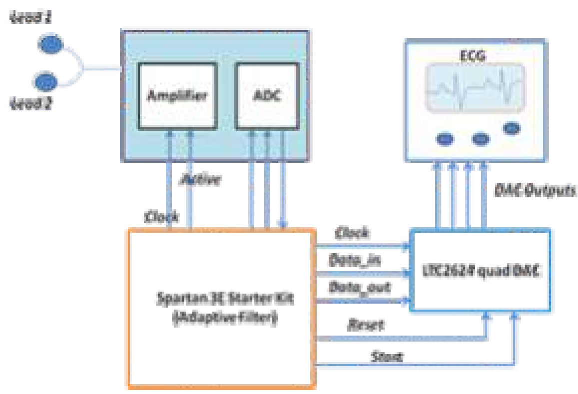

Fig.2. Block diagram of Adaptive filter on Onboard ADC and DAC of Spartan 3E FPGA

Now, we will discuss in detail about each component in the design.

a) ELECTROCARDIOGRAM (ECG)

The frequency range of an ECG signal is 0.05-100 Hz and its dynamic range is 1-10 mV The execution of ECG breaking down framework depends for the most part on the exact and dependable identification of the QRS, and additionally T-waves and P-waves. The QRS complex and T-wave speak to the excitation of the ventricles or the lower council of the heart, where as the P-wave represents the activation of the upper chambers of the heart. The normal value of heart-beat lies in the range of 60 to 100 beats/minute. A slower rate than normal value is called bradycardia (Slow heart) and a higher rate are called tachycardia (Fast heart). The changes in ECG were characterized as Q-waves (1.1x-1.3x), ST-fragment discouragement (4.1-4.3), T-wave changes (5.1-5.3), left ventricular conduction abandons (7.1x and 7.2x), and left ventricular hypertrophy (3.1 and 3.2).The two later changes were regarded as major ECG changes.

b) ELECTRODES

Two electrodes are used with one side attached to the human body and other to an ECG. A gelly Ag/AgCl is the most extensively used electrodes as they minimize the effect of polarization and drop contact potential. They perform the conversion of Ionic current inside the human body into electronic signals outside, which is nothing but the functionality of a transducer.

c) ANALOG TO DIGITAL CONVERTER (ADC)

The ADC and Amplifier used here is a 14-bit LTC1407-1 dual channel A/D Converter and LTC6912-1 dual channel programmable amplifier provided on the Spartan 3E Starter Kit [6]. The ADC reference voltage is 1.65V with a maximum range of ±1.25V. The analog input to the ADC is given from the human body on the VINA on J7 header present on Spartan 3E Starter Kit. The output is presented to the FPGA which is programmed to work as an Adaptive filter.

d) ADAPTIVE FILTER

Adaptive Filtering have wide applications in DSP and communications which involve change of filter coefficients with time, varies with changing signal/noise characteristics and extracts useful information from noisy and unwanted data[7][9][12]. Adaptive filter process non stationary signals that learns about the statistics features of the environment and continuously adjusts in correspondence to where the desired processing operation is not known [10][11] as shown in Fig.3.

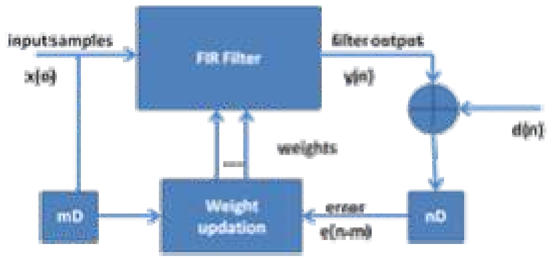

Fig.3. Block Diagram of Adaptive Filter

Here, the digital output from the ADC is processed by comparing it with the desired signal and any glitches or unwanted data is eliminated. In this work, the signals from the ECG pass through the Adaptive filter and are enhanced in their quality, especially the T-waves which play the most crucial role in detecting CVDs. The Adaptive filter comprises of different algorithms of which we use Least Mean Square (LMS) or Recursive Least Squares (RLS). The output of this filter is given to the DAC[14].

e) DIGITAL TO ANALOG CONVERTER (DAC)

The DAC used here is a 12-bit unsigned resolution LTC2624 quad D/A Converter provided on the Spartan 3E Starter Kit [8]. The DAC supply ranges from 2.5V to 5.5V. The inputs to the DAC are from the adaptive filter and the four outputs are seen on the J5 header. The outputs are given to the ECG monitor.

IV. DESIGN AND IMPLEMENTATION

The electronic signal obtained from the electrodes connected to the human body is given as an input to the ADC which converts the analog signal into a digital one. This digital data is given to the adaptive filter where the input signal is compared with the desired signal and the error is calculated. The T-wave in the ECG input is enhanced and is given to the DAC. It converts the digital signal into 4-channel analog output which is displayed on the ECG monitor. By observing the ECG waves, the occurrence of cardiovascular diseases will be detected.

MATLAB Simulink® is an information stream graphical programming language apparatus for demonstrating and modiling. It is used to analyze, model and simulate the dynamic characteristics of Adaptive filter by using block diagrams as shown in Fig.4.

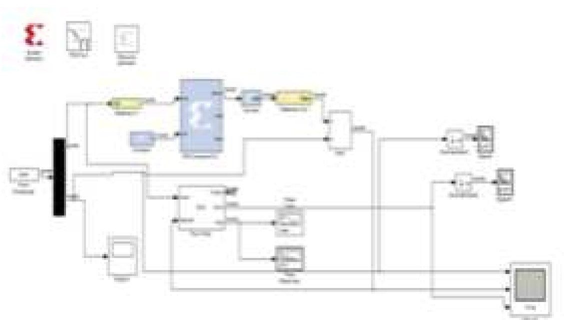

Fig.4. ECG using Adaptive filter

The adaptive filter that is developed using MATLAB Simulink® is converted into a synthesizable VHDL code using HDL generator. This obtained VHDL model is integrated with an ADC and DAC and implementation is done on Spartan3E FPGA kit using Xilinx ISE 14.2 Design Suite[13].

V. RESULTS

ECG signal from MIT-BIH database for T-waves were tried for the testing of the Digital Adaptive Filter using Xilinx Block Set in Matlab Simulink® and is verified for the performance. The results obtained are as shown in the Fig.5.

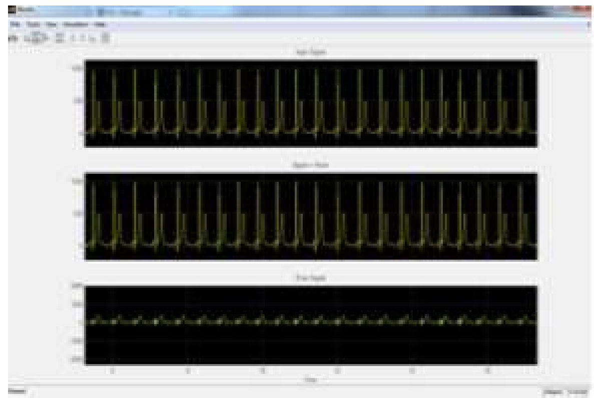

Fig.5. Output Waveforms

The final output signal suppressed the PQRS wave information which is of no interest and enhanced the T wave which is of more importance and the harmonics are also enhanced as shown in Fig.6.

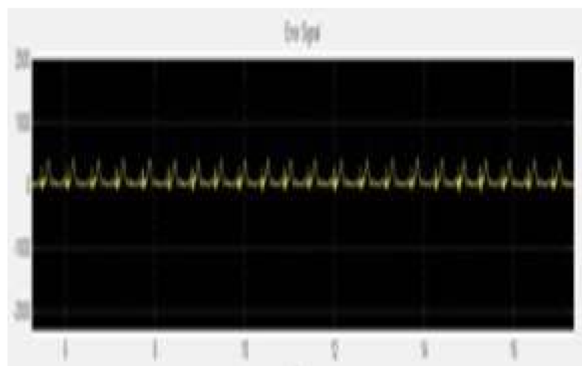

Fig.6. Enhanched T-waves

VI. CONCLUSION

The ECG correlation based Adaptive filter was successfully implemented on Spartan 3E Starter Kit to form a complete system that streams analog data in and out. The results showed that this system could stream in a mixed signal containing ECG waves, process the data within the FPGA, and stream out an analog signal which has the ECG wave unaffected. It easily removed ECG artifacts and enhanced T-waves for detecting sudden cardiac deaths. In this way, Automated arrhythmia detection would not only help in early detection of diseases but also in reducing the workload of medicaldata analyst.

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