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IMPLEMENTATION OF ECG SIGNAL USING ACF ALGORITHM

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Abstract: ECG is considered as the one of the standard for heart rate monitoring and also for the diagnosis of different cardiac problems. The QRS complex is one of the most important feature in the ECG signal. The duration and height of the QRS complex delivers a significant amount of data to the physician thereby helps him in assessing the condition of the heart. The noise and the other artifacts contaminate the ECG signals. This makes the analysis difficult with the naked eye. There are different algorithms developed to find the different features of ECG signal. In this project we introduce mainly two algorithms namely a Pan- Tompkins Algorithm and Autocorrelation Function Algorithm to find the QRS complexes of the 12-lead ECG signal. The MATLAB software is used for simulation of this system. The methodology is divided into two parts which is software and hardware. The first part is simulation for this system by using Matlab. The QRS complex detection is determined by using Autocorrelation Function and Pan-Tompkins Algorithm. This thesis presents a method for the design and implementation of detection of QRS complexes by using Autocorrelation Function Algorithm on Field Programmable Gate Array (FPGA) . The reason for hardware implementation on FPGA is for the fact that the FPGA supports for the faster prototyping and can be reprogrammed quickly. They are inexpensive and easily testable. This feature enables the faster implementation and verification of the new designs. The approach gives the more accurate results in real time ECG signal analysis.
Key Words: Pan Tompkins algorithm, Autocorrelation Function Algorithm, Band pass filter, differentiator, moving window.

I. INTRODUCTION

One of the diagnosis tool which reports the electrical activity of heart which can be recorded by skin electrode is Electrocardiogram (ECG).The heart rate and morphology shows the health of the human heart beat. This technique is non invasive which means the signal is measured on human body surface. These signals are used for the prediction of heart diseases. The cardiac arrhythmia indicates any disorder of heart rhythm or rate or change in the morphological pattern. This could be detected by analysis of recorded ECG waveform. The amplitude and duration of the P-QRS-TU wave gives the information about the type and nature of disease that has affected to the heart and de-polarization and re-polarization of Na+ and K- ions in the blood results in electrical waves. The following information of the human heart can be obtained by analysis of ECG signals.

- It provides Electrolyte concentration changes.
- It provides a conduction disturbances , heart rate.
- It provides impulse origin and propagation informations.
- It provides location and extent of myocordial ischemia.
- It provides information on effect of drug on the heart.
- It provides information on relative chamber size of heart and its position.

A. The Heart Anatomy:
The human heart has 4 chambers. They are:

- Right atrium.
- Left atrium.
- Right ventricle.
- Left ventricle.

There are several atrioventricular and sinoatrial node. They are shown in the figure below:

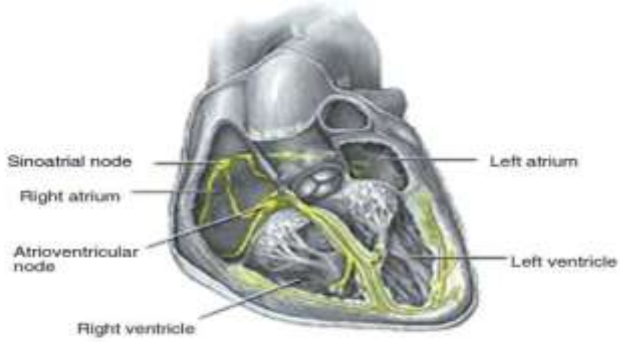

Fig 1: Anatomy of the Heart

The upper two chambers are known as the left and right atria, where as the lower two chambers are called the left and right ventricles. The atria and ventricles are connected by fibrous and non-conductive tissue, which keeps ventricles and atria electrically isolated. The blood is circulated to the lungs by the pumping action of right atrium and right ventricle. The oxygen poor blood flows into right atrium through large veins called inferior and superior vena cava. The blood is forced into the right ventricle by the contraction of right atrium, at the same time the ventricle is stretched and maximizes the pumping efficiency. The blood is pumped into the lungs by the right ventricle and gets oxygenated. The oxygen riched blood is pumped to the rest of the body by the pumping action of left ventricle and left atrium combination.
In the heart regular electrical impulses are generated by ‘sinoatrial’ node. These impulses then spread through the

conduction system of the heart there by initiating contraction of myocardium. The de-polarization is the process in which electrical impulses are propagated through an excitable tissues. A strong ionic current is collectively generated by the de-polarization of heart muscles. Thus a voltage drop is generated when this current flows through the resistive body tissue. This voltage drop is large enough to be detected by the electrodes that are attached to the skin .Therefore ECG is nothing but recording of the voltage drop that exists across the skin which is due to the ionic current flow caused from myocardial de-polarization. The sprading of electrical impulse which is resulted by atrial de-polarization through the atrial myocardium forms the P-Wave and also the spreading of electrical impulse throughout the ventricular myocardium is resulted by ventricular de-polarization.

B. Principle methods for ECG analysis:

As the digital electrical cardiography is designed as a main method for ECG in data acquisition for automatic ECG analysis, an intense research activity has been focused on automatic QRS complex detection. Within the ECG, the QRS complex is the most valuable waveform, its detection is the main step in every automated ECG analysis algorithm. The QRS waveform acts as the reference point for the determination of automated heart rate. The useful information of the present state of the heart is given by the detection, analysis and extraction of QRS waveform.

C. QRS detection –brief review:

Artificial Neural Networks, Genetic algorithm, filter banks and Wavelet transforms have been developed for the purpose of QRS detection and analysis. In artificial neural networks method QRS detection is done by Neural Networks by training adaptive non-linear ECG signal predictors. In filter banks method an estimate of ECG samples are obtained by a number of adaptive filters and the estimate is then given as a weighted summation of the previous samples. In wavelet transforms method uses signal derivatives for detection of slopes of QRS complex and cross correlation methods. In this the first template is given to the present ECG signal , and syntactic approaches in which ECG signal is represented as a piecewise linear approximation and then analyzed by using the syntactic rules. All most all the algorithms uses the same structures – preprocessing stage , feature extraction stage and a decision stage. One of the approach which follows the above said stage is the “Pan-Tompkins algorithm”. It consists of a bandpass filter to cut off the high , low and the DC noises, a differentiator and a squaring operator which enables the steep prominent features and also an adjustable moving window integrator for smoothing. In this method for QRS signal detection, filter threshold method is used. For normal QRS complexes the Pan-Tompkin Algorithm is very good but when it comes to the detection of abnormal such as wider QRS complexes , the performance will be rather poor. In case of Auto-Correlation Function based algorithm we use pre-processing stage that follows bandpass filter to cut off high, low and the Dc noises, a differentiator. This algorithm has the advantage of detection of more diseases. It also analyzes all peaks and inter peak interval signals of the heart when compared to Pan-Tompkins algorithm.

II. LITERATURE SURVEY

For performing the given task, the needed background is presented in this chapter. The initial phase of the project highlights the material relevant to the given task. Different algorithms have been proposed to find the QRS complex of ECG signals. Also explains the contributed work of the previous researchers. The biomedical background required for the given project is presented in this section. It is necessary to understand Electrocardiogram(ECG),the arrangement of different leads of the ECG signals and also how the signals are interpreted. Once the Electrocardiogram is understood, the algorithms that are necessary for processing the leads of ECG signals are studied.

A. Wavelet transform based algorithm:

A wavelet based time frequency analysis of ECG signal is explained. The ECG records the electrical activity of the heart and there by gives the valuable information about the heart disorders, the patient is suffering depending upon the variation of the ECG signal from the patient and the normal ECG signal pattern. In this algorithm the co-efficient of an ECG signal at a given scale shows the presence of QRS signal efficiently without considering the noise and the unusual larger amplitude of signals present other than the QRS peaks. Here the wavelet transform of a continuous co-efficient signals are plotted by using Morlet wavelet.

B. Peak detector algorithm:

In this algorithm ECG signal is applied using 167ms window. They are divided into three segments of 55.6ms. In this 360 BPM is the maximum beat frequency that is detectable. Here the maximum value is searched by the algorithm which scans the whole range. This algorithm tests for the maximum value and finds whether the value is on the central segment and also whether it is higher than a certain threshold. If it true then the position is taken as a beat and its amplitude is saved as the new threshold.

C. Single – channel QRS (SQRS) detector:

This algorithm makes use of FIR filter and it is based on length transform. It uses FIR filter as an approximation to the ECG signal slope. From the artifacts it detects and identifies QRS complexes by using a variable threshold. the algorithm saves the time and enters a decision phase provided the filtered signal is greater compare to threshold. within 160ms 2 to 4 of these detections of each other shows that the normal beat is present. If more than 4 detections are performed within 200ms of each other it indicates as an artifact. Once the decision is made the algorithm is reset. If no detection is made once in every 2 seconds , the threshold is reduced by 1/16th and if more than 4 detections are made then the threshold is increased by 1/16th . The threshold is recalculated each time , the normal beat is detected.

The above said algorithms are failed to detect the QRS complexes of ECG signal in real time. But our thesis will overcome these problems easily by using ACF algorithm. This thesis presents a method for the design and implementation of detection of QRS complexes by using Autocorrelation Function Algorithm on Field Programmable Gate Array(FPGA) . The reason for hardware implementation on FPGA is for the fact that the FPGA supports for the faster prototyping and can be reprogrammed quickly. They are inexpensive and easily testable. This feature enables the faster implementation and verification of the new designs. The approach gives the more accurate results in real time ECG signal analysis.

What is ECG?
Electrocardiogram can be defined as the pictorial representation of the "electrical activity" of the heart. There are two terms they are EKG and ECG. "EKG" stands for Electrokardiogram which was proposed by Willem Einthoven, a Dutch Physiologist in 1890's.The second term "ECG" is the English version Electrocardiogram and it is commonly used today. In the beginning, the ECG consisted only 3 limb leads and were the main limb leads. Later on in 1930, six chest leads were introduced and then 3 augmented limb leads were added in 1942.This finally resulted in 12 lead ECG which is used nowadays.

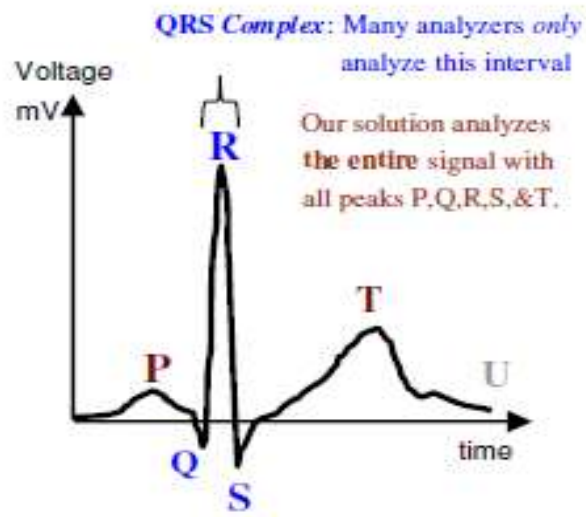

Fig 2: ECG waveform

III. IMPLEMENTATION

A. PAN TOMPKIN ALGORITHM:

The algorithm that can be used for the analysis of ECG signals is Pan Tompkin algorithm. This algorithm detects whether the heart beat is normal or not. Therefore this algorithm mainly detects QRS interval only. Most of the ECG instruments need the presence of precise QRS detector. It combines three types QRS detection. They are:

- Linear digital filtering.
- Non-linear transformation.
- Decision rule algorithm.

The block diagram of the Pan Tompkin algorithm is shown below:

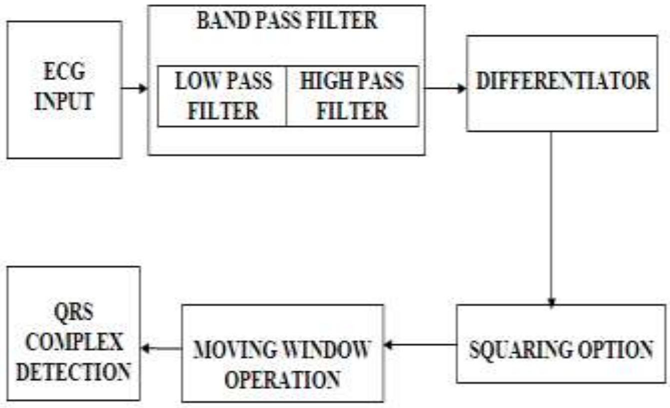

Fig 3: Block diagram of the Pan Tompkin algorithm

1)ECG input:
The 12 – lead ECG sensors are placed on the patient's body at different appropriate points. The output of these sensors forms the input signal.

2) Band pass filter :
This stage consists of low pass and high pass filters. They together form a band pass filter. The ECG signal is limited initially at 50 Hz and then sampled at a signal of Fs = 200 Hz and the ECG input is passed to this block to remove high frequency noise, P waves, T waves and unwanted artifacts.

3) Differentiation:
The differentiation of the filtered ECG signal is done in order to remove the moving artifacts and also used to increase the SNR . This contains the information regarding the slope of QRS.

4) Squaring:
The output from the differentiation block is sent to squaring block. The squaring process increases the slope of the frequency response of this differentiated signal in order to help the detection of false peaks like the T waves.

5) Moving window:
The signal from the squaring option is passed on to moving window integrator. This is to obtain information regarding the width of the QRS complex. This information is next passed through the local peak detection and the threshold setting algorithm as the original band passed filtered signal. This is to identify QRS slope information.

6) QRS complex output:
All the QRS peaks that are present in the filtered and transformed waveforms are compared only the signal appearing in both processed waveform are considered as valid QRS complexes.

B. AUTOCORRELATION FUNCTION (ACF)ALGORITHM:

One of the algorithms that can be used for the analysis of ECG signals is Autocorrelation function algorithm. This algorithm has an advantage of detecting the additional

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diseases of the heart along with function of the heart beat. This algorithm not only detects QRS interval but also finds the other peaks of the ECG signal. Most of the ECG instruments need the presence of precise QRS detector. It combines three types QRS detection.

- Linear digital filtering.
- Non-linear transformation.
- Decision rule algorithm.

The block diagram of the Autocorrelation function algorithm is shown below:

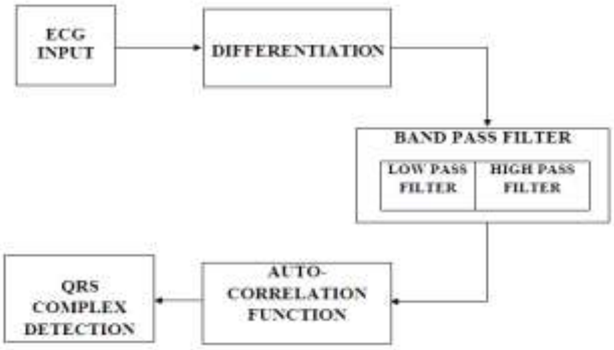


Fig 4: The block diagram of the Autocorrelation function algorithm

1) ECG input:
The 12 – lead ECG sensors are placed on the patients body at different appropriate points. The output of these sensors forms the input signal.

2) Differentiation:
The differentiation of the ECG signal is done in order to remove the moving artifacts and also used to increase the SNR . This contains the information regarding the slope of QRS.

3) Band pass filter :
This stage consists of low pass and high pass filters. They together form a band pass filter. The ECG signal is limited initially at 50 Hz and then sampled at a signal of Fs = 200 Hz and the output differentiated signal is passed to this block to remove high frequency noise, P waves, T waves and unwanted artifacts.

4) Autocorrelation Function:
The output of the band pass filter is passed through the autocorrelation function in order to find the duration of the a cardiac cycle present in the ECG signal. For analyzing the period between the two peaks , the relationship of the function repetitiveness to itself by using the characteristics of autocorrelation is implemented in this block.

5) QRS complex output:
In this block we detect the period first and after that we look for the peaks instead of looking for R peaks and there by detecting the period through autocorrelation. Due to the high degree of randomness present in the ECG signal we go for this type of approach to find QRS complex.

EQUATIONS
The main concept is to run autocorrelation function on the function y over the recorded data sample. we get ACF coefficients as below:

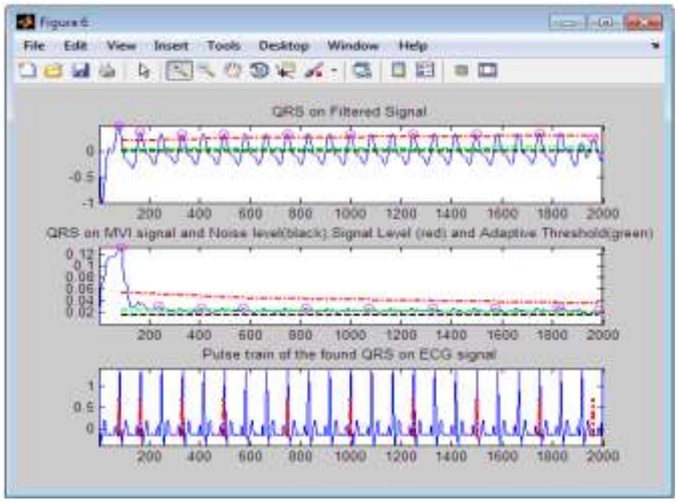
$$R_y[k] = \sum_{n=-\infty}^{n=\infty} y[n] \times y[n-k]$$

Where,
Ry = Autocorrelation function
y[n] = ECG filtered signal.
k = Number of lags of autocorrelation.

IV. RESULTS

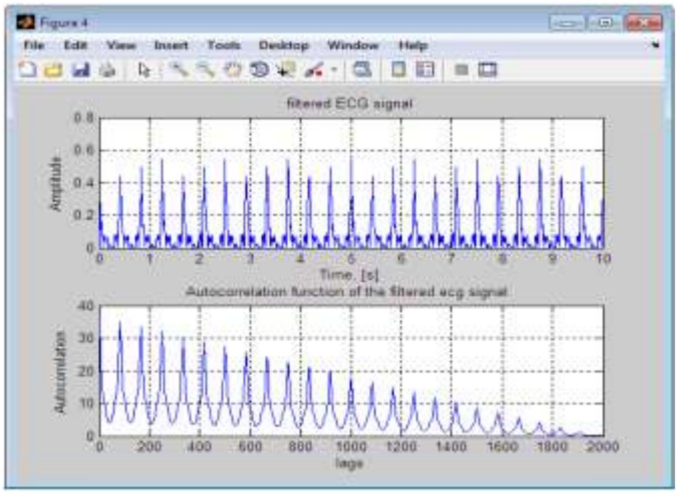
MATLAB RESULTS:

A. PAN-TOMPKINS ALGORITHM:



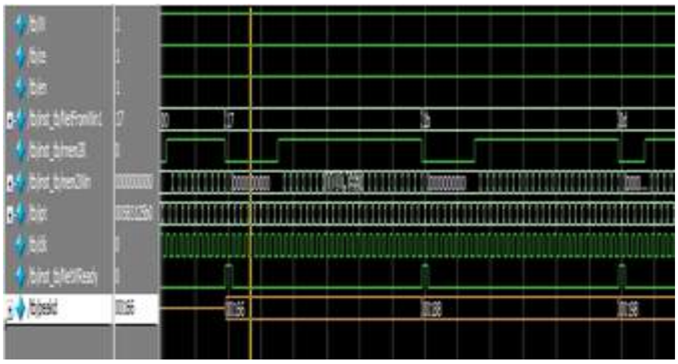
The above figure shows the output of the Pan-Tompkins Algorithm. The x-axis represents the number of samples and y-axis represents the amplitude of the ECG signal.

B. ACF OUTPUT:

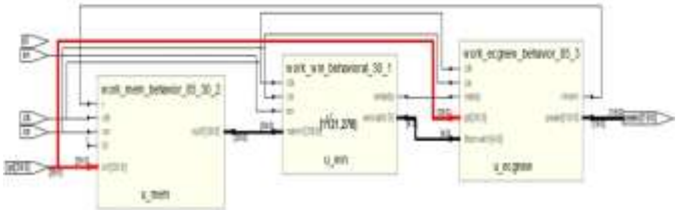


The ECG signal obtained from the band pass filter is applied to the auto correlation function. In this the signal is correlated by itself. The figure above shows the output of autocorrelation function.

C. FPGA OUTPUT:



RTL SCHEMATIC:



DEVICE UTILIZATION MEMORY:

Logic Utilization	Used	Available	Utilization	Note(s)
Number of Slice Flip Flops	354	1,920	18%	
Number of 4 input LUTs	604	1,920	31%	
Logic Distribution				
Number of occupied Slices	466	960	48%	
Number of Slices containing only related logic	466	466	100%	
Number of Slices containing unrelated logic	0	466	0%	
Total Number of 4 input LUTs	770	1,920	40%	
Number used as logic	604			
Number used as a route-thru	166			
Number of bonded IOBs	63	108	58%	
IOB Flip Flops	40			
IOB Latches	20			
Number of Block RAMs	2	4	50%	
Number of GCLKs	2	24	8%	
Number of MULT18X18SIOs	4	4	100%	
Total equivalent gate count for design	140,890			
Additional JTAG gate count for IOBs	3,024			

V. CONCLUSION

An Auto Correlation Function Algorithm and Pan-Tompkins Algorithm methods are used to find out the QRS complex (R-R interval) detection to check whether the ECG signal is normal or abnormal. The implementation of ECG signal using ACF algorithm is done successfully on FPGA. By this analysis we get a solution for a large medical problem like Cardio Vascular Disease (CVD) and stroke, which leads yearly to the highest number of deaths. This solution paves the way for novel healthcare delivery scenarios and for accurate diagnosis of heart-related diseases.

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