IMPLEMENTATION OF HEART RATE VARIABILITY ANALYSIS ALGORITHM ON FPGA PLATFORM

Project report submitted in partial fulfilment of the requirement for the degree of

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DECLARATION BY THE SCHOLAR

We hereby declare that the work reported in the B.tech thesis entitled **”Implementation Of Heart Rate Variability Analysis Algorithm Using FPGA Platform”** submitted at **Jaypee Univerity Of Information Technology,Waknaghat India**, in an authentic record of my work carried out under the supervision of **Dr.Harsh Sohal** (Assistant Professor, Department Electronics and Communication Engineering).We have not submitted this work elsewhere for any other dergree or diploma.

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LIST OF ABBREVIATIONS AND ACRONYMS

S.NO	ABBREVIATION	FULL FORM
1.	ECG	ELECTRO CARDIOGRAPY
2.	HRV	HEART RATE VARIABILITY
3.	SA	SINO ATRIA
4.	AV	ATRIO VENTRICULAR
5.	HR	HEART RATE
6.	SNR	SIGNAL TO NOISE RATIO
7.	LMS	LEAST MEAN SQUARE
8.	FFT	FAST FOURIER TRANSFORM
9.	DFT	DISCRETE FOURIER TRANSFORM
10.	STFT	SHORT TERM FOURIER TRANSFORM
11.	CWT	CONTINUOUS WAVLET TRANSFORM
12.	DWT	DISCRETE WAVELET TRANSFORM
13.	FPGA	FIELD PROGRAMMABLE GATE ARRAY
14.	ASIC	APPLICATION SPECIFIC INTEGRATED CIRCUIT
15.	IC	INEGRATED CIRCUIT
16.	DSP	DIGITAL SIGNAL PROCESSING
17.	EMG	ELECTROMYOGRAPHY
18.	CLB	CONFIGURABLE LOGIC BLOCKS
19.	SRAM	STATIC RANDOM ACESS MEMORY
20.	COTS	COMMERCIAL OFF THR SHELF
21.	IP	INTERNET PROTOCAL

22.	NRE	NON RECURRING ENGINEERING
23.	OS	OPERATING SYSTEM
24.	OTP	ONE TIME PROGRAMMABLE

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ABSTRACT

ECG devices in use today are bulky and unwieldy for patients to use for long-term health monitoring and expensive too. However, with the advancement of scientific techniques and research, advanced patient monitoring techniques have been developed for tracking patient conditions. ECG characteristic extraction has been studied from early time and masses of superior strategies in addition to changes had been proposed for correct and speedy ECG feature extraction. Field Programmable Gate Arrays (FPGAs) are semiconductor devices that are based around a matrix of configurable logic blocks (CLBs) connected via programmable interconnects This project “Implementation of heart rate variability analysis algorithm using FPGA platform “will help the people with heart diseases and analysis can be done quickly. During emergency, an alarm can be sent to the hospitals and relatives so that speedy treatment could be given to the patients .Hence ,this project is will help in diagnosis and will eliminate the need for transportation at the eleventh hour.

CHAPTER 1

INTRODUCTION

The inevitable need of regular and frequent check-ups and concern for the health has raised the interest of the developers to make the newest and innovative designs of the medical instruments or devices possible for the needy. In this respect devices had played an important role in the early and rapid warning of heart and diagnosis of cardiovascular diseases. Development of ECG diagnostic equipment is thus a result of such a human need and has gained highest priority. However, ECG devices in use today are bulky and unwieldy for patients to use for long-term health monitoring and expensive too. However, with the advancement of scientific techniques and research, advanced patient monitoring techniques have been developed for tracking patient conditions. But still there a remains a question mark on their efficacy and working. Thus, it can be said that despite recent progress in novel sensing devices, the standard of care for most physicians and healthcare systems remains the periodic observation of patients' vital signs.

1.1 HEART RATE

Heart rate of a person can be defined as number of times heart beating per minute . Usually the heart rate changes from one person to another. The change in the heart rate depends on certain factors. With the growing age the heart rate and pulse change show a significance variation. Such a variation may lead to indication of certain signs in the body which require immediate attention. The count of the heart beats per minute or in 60 sec can be done by putting your finger over the pulse in hand. This results in accurate readings.

The different state of the body leads to varying heart rates- Resting heart rate is basically the lowest amount the blood the heart is pumping as there is no exercise included. Another, point is that if one is sitting or lying or in a clam state and is free from diseased or illness state then the heart rate remains between 60-100 beats per minute and this considered as normal. There can be certain conditions where lower heart rate can be reported but this may necessarily not a result of any medical problem, drug (beta blocker) intake may the heart to beat at a lower rate of 60 beats per minute.

Other cause for lower heart rate is greater physical activity, usually the heart rate of a healthy person is low as the heart is in proper condition and no extra work has to be done by the heart to maintain the heart beat. Physical activities do change the heart rate but if moderate physical activity is practised then usually change in the pulse is not so significant. However, fitness may lead to a 40 minutes per minute heart rate. Lesser activity might have a heart rate between 60 and 100 as they have to work harder to main the functions of the body and make it higher

There are certain aspects affecting the heart rate:

- **Temperature of air:** Increase in temperature and the humidity) increases the pulse rate up to 5 to 10 beats per minute.
- **Position of the body:** Resting, sitting or standing, doesn’t makes the pulse vary too much. Standing for the first fifteen to twenty seconds, increases the pulse rate but after few minutes it come back to normal.
- **Emotions:** Emotions certainly effect the pulse rate. Stress, anxiety or “extraordinarily happiness or sadness” increases the heart rate.
- **Body size:** Body size usually doesn’t change pulse. However, obesity condition might leave an individual with resting pulse more than normal person, but not more than 100 beats per minute.
- **Medication use:** Different kinds of medications have different effect on the pulse. There are many medicines that block adrenaline, which slows down the heart rate. Use of thyroid medication in huge amount will raise pulse rate.

1.2 HEART RATE VARIABILITY

HRV i.e. the Heart Rate Variability that can be measured as the change in time between successive heart beats. It is also known by the name inter-beat intervals, R-R intervals, N-N intervals. This interval in the heart beat can be about 0.95 secs between two succeeding beats or even greater like 1.25 secs between the other two succeeding heart beats. Such a difference which can be measured in seconds can also be felt also.

HRV is generally observed to gain knowledge about proper working of the nervous system as it is closely linked with the Autonomous system. Beside the nervous system - stress and recovery are the other significant areas which can be studied with HRV.

Electrocardiogram is the golden method of measuring the HRV.ECG or pulse wave recording is the golden method to measure HRV.ECG shows the electrical activity of one's heart. When measured through ECG, HRV is the measure of variation in the R-R intervals of heart beat.

A broad range of applications of the heart rate variability analysis can been enhanced to cope up with the conditions in the future generations such as elevated stress levels, depression, overweight, anxiety disorders, anger management issues and many more. The other significant functions of HRV are –

1) Prediction of arrhythmic events or sudden cardiac death after acute MI, and
2) Medical marker of evolving diabetic neuropathy.

1.3 ECG

Electrocardiogram is basically a diagnostic tool which assesses the muscular and electrical functions of the heart. It bills for the electrical activity of the heart. It's a graphical representation of the version of electrical activity against time. It is one of the simplest tests medically. It helps to study the heart activity which can be done by placing the electrodes on the chest. ECG also measures the rhythm and rate of the heart. It has reported that ECG too gives indirect information about the flow of the blood.ECG requires a standardised working system in which the leads connected to the ECG are placed on the certain specified positions on the body. The recording is done on the ECG machine or on graph papers or on monitors. In order, to know the working of ECG it is important to understand the working of the human heart. The human coronary heart contains four chambers i.e., RightAtrium, LeftAtrium, RightVentricle and LeftVentricle. The upper two chambers are atria's and lower ones are called ventricles. The electrodes in the ECG are basically placed or can also be adjusted following the standard nomenclature i.e. Right arm, left arm, Right leg and Right arm. However, this can be varied according to the requirement. One more thing to be noted about the electrodes is that they are basically wet sensors and require gel for enhancing conductivity between the skin and the electrodes.

Under normal conditions the pulse begins at the right Atrium known as the Sino Atria (SA) node and a unique group of cells transfer these electric signals throughout the cardiac system. This sign travels from the Atria to the Atria-Ventricular (AV) node. The Atria – ventricular (AV) node connects to a group of nerves in the Ventricles that conducts the electrical signal and transfer the impulse pulse to the lower chamber, the Ventricles. To ensure that the coronary heart is functioning properly the direction in which the signal is travelling should be traced. Waves, periods, segments and one complex, are parts of the electrocardiography (ECG) which can be described as follows:

Wave: A deflection from baseline basically depicts a selected electric event. The waves on an ECG consist of the P wave, Q wave, R wave, S wave, T wave and U wave. Articular and ventricular depolarisation and repolarisation are represented as of series of waves.

Interval: The time among specific electrocardiography (ECG) activities. The periods normally analysed on an ECG encompass the PR segment, QRS complex(also referred to as QRS duration), QT interval and RR interval.

Segment: Segment are primarily used to observe the shift from the iso-electric line. The PR segment, ST segment and TP segment. are the segments of the electrocardiography signal(ECG), the PR segment that starts at the completion of the P-wave and ends at the QRS complex.ST segment is the other major segment it starts at the end of the S-wave and ends at the beginning of the T-wave. The TP segments starts at the end of the T-wave and ends at the beginning of the P-wave.

Complex: Multipled waves grouped together. The main complex of the electrocardiography (ECG) waveform is the QRS complex which is in turn the combination of the Q-wave, R-wave and S-wave.

Point: One point only exists in the electrocardiography (ECG) waveform, the J point situated at the end of QRS complex and the beginning of ST segment, R-wave and R-wave deflection. Positive deflection in the J-point is known as J-wave or Osborn wave. This wave is the characteristic of hypothermia.ST segment abnormalities causes elevations and depressions in J-point.

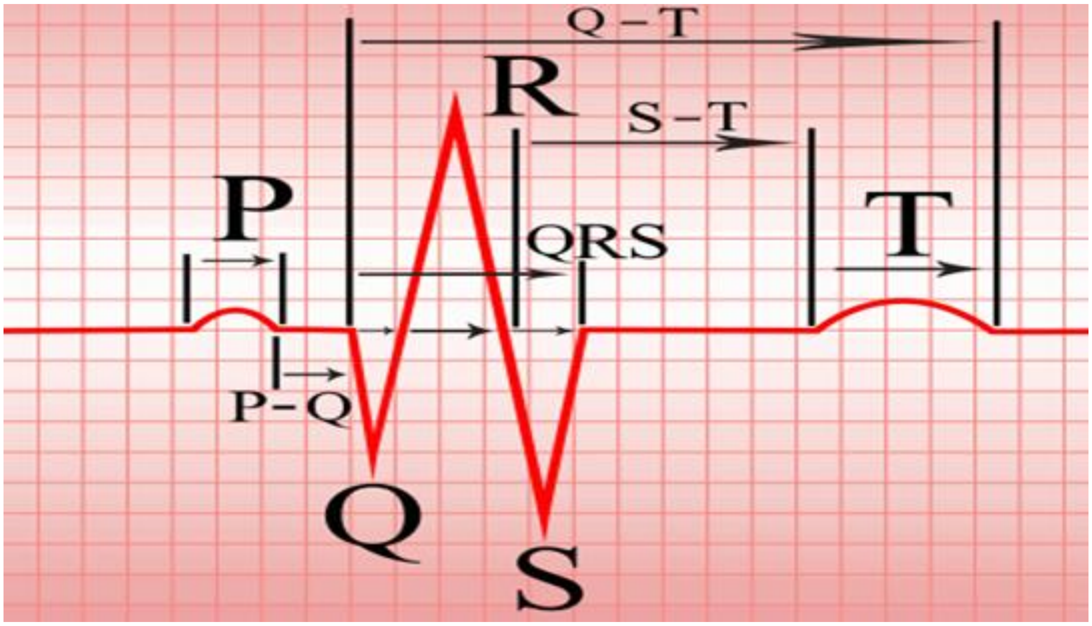

Figure 1.1:ECG waveform

1.4 SEGMENTS OF ECG

P Wave

The P wave indicates atrial depolarization. It is a small, positive wave. Smooth in working. The P-wave duration should be less than or equal to 0,12 seconds. The P-wave is always and usually positive in sinus rhythm. It occurs when the sinus node, also known as the sinoatrial node, creates an action potential that depolarizes the atria. so as the atrial depolarization is able to spread through the atrioventricular (AV), node to the ventricles, every P wave ought to be accompanied by a QRS complex. Trial enlargements can widen the P wave or increase the P wave amplitude-pulmonale is the wave that's displayed when higher amplitude is basically displayed in lead II and lead V1. P-mitrale on the other hand If the left atrium meets with increased resistance then it contributes to the enhancement in the P-wave. This is because of the mitral valve stenosis. Hence the P-mitrale, as the mitral valve complexities and disease is the common cause of such a condition.

PR Segment

The PR segment is the section of the electrocardiography (ECG) from the finish point of the P wave to the start of the QRS complex. PR segment is flat in appearance. The PR segment differs from the PR interval,. The crucial element in analysing segments at the electrocardiography (ECG) is their deviation from the isoelectric line — that is, elevation or melancholy — whereas the most essential component in reading periods is their duration. even though abnormalities of the PR section are not very not unusual, they are able to indicate certain cardiac disease states. PR section melancholy may be a signal for pericarditis or atrial infarction. The other abnormality of the PR segment is Atrial ischaemia. Where elevation or the depression in the PR segment in the patients with the myocardial infarction indicates concomitant Atria ischaemia.

Q Wave

The first deflection after the P wave and the first detail inside the QRS complex is known as the PR segment .No Q wave is present, is the foremost QRS complex is upright. Abnormality of the Q waves is generally indicative of myocardial infarction. The phrases “Q wave myocardial infarction” and “non-Q wave myocardial infarction” are earlier designations of various types of MIs in the long run ensuring in, respectively,in development and absence of development of Q waves. The Q wave is taken into consideration pathological if more than 40ms or 2mm deep. There is 25% depth in the QRS complex. Q-waves in the normal conditions are not seen in the right side of the leads.

R Wave

R wave is the primary upward deflection after the P wave ,and the most important QRS complex.. It represents early polar depolarization. The R wave turns into large — to the extent that R wave is bigger than the S wave. The S wave turns into pretty small; known as “regular R wave progression”. The key abnormalities of the R-wave are (i) Dominant R-wave in V1(ii) Dominant R-wave in VR(iii)Poor R-wave progression.

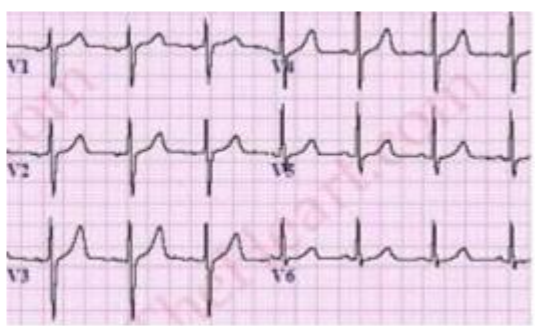

FIGURE 1.2: Normal R-wave Progression

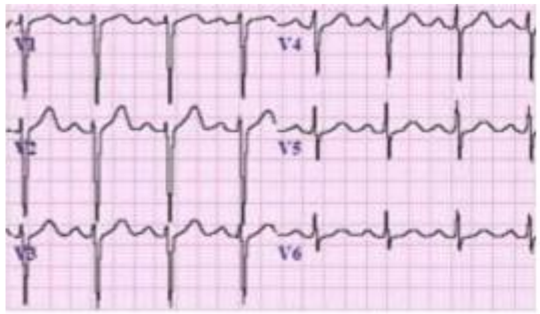

FIGURE 1.3: Poor R-wave Propagation

S Wave

S wave is the primary downward deflection of QRS complex that takes place after R wave. S wave travels opposite to the direction of the R-wave. However, a S wave is not found in all electrocardiography (ECG) signals. Morphology of the S wave is studied to decide if ventricular tachycardia or supraventricular tachycardia with aberrancy is present.

QRS Complex

A combination of Q wave, R wave and S wave, the “QRS complex” represents ventricular depolarization. These three appear in rapid succession. They basically present a single event and the regular duration of the QRS complicated is among zero.08 and 0.10 seconds — that is, eighty and one hundred milliseconds. while the duration is among 0.10 and 0.12 seconds. QRS duration of extra than 0.12 seconds is taken into consideration bizarre. The duration is short in children and in myocardia. Longer duration of the QRS indicates hyperkalaemia.

The QRS complex duration will increase whilst electric activity takes longer time throughout the ventricular myocardium. The normal conduction device in ventricles is called the “His-Purkinje” system,consists of cells which could behavior energy quite hastily. This complex is also used to study the QT interval.

T Wave

T wave takes place after the QRS complex resulting from ventricular repolarisation. Further, T waves is usually asymmetric by nature. T-wave also indicates recovery of the ventricles. In maximum of the leads the T-wave is symmetrical. From the T-wave greater statistics about the QT phase can be won. The ultimate 1/2 of the T-wave is mentioned to have relative refractory duration. at the equal time because the begin of the QRS complicated up to the apex of the T-wave is named as absolute refractory length. the second one part of the T wave must have a steeper decline even in contrast with the incline of the foremost element. If T wave seems symmetric, cardiac pathology at the side of ischemia can be present.

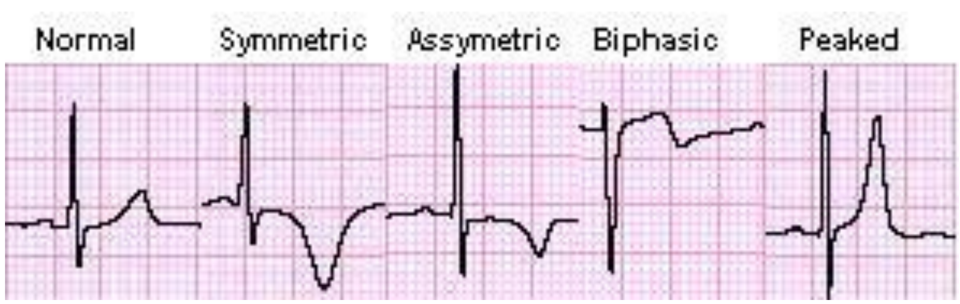

FIGURE 1.4: ABNORMALITIES IN T WAVE

QT Interval

QT interval is from the start of the QRS complex, representing ventricular depolarization, to the ending of T wave, as a consequence of ventricular repolarisation. In popular, the normal QT interval is beneath four hundred to 440 milliseconds (ms). Women tend to have an extended QT interval than men.Low coronary heart costs also bring about an extended QT interval. It's miles the time between the begin of Q-wave and the cease of the T -wave.

ST Segment

It starts offevolved on the J-factor. It connects the QRS complex and the T-wave. It has a normal length of five to a hundred and fifty ms. ST segment has got a moderate upward concavity. ST segment belongs to the electrocardiography(ECG) from the ending of the QRS complex to the beginning of T wave. ST phase usually stays isoelectric; for that reason, ST segment depression or elevation can indicate cardiac hypokalaemia. The ST segment is carefully analysed on the ECG for the detection of myocardial ischemia**.**

TP Segment

The TP segment is a segment of the electrocardiography (ECG) from the ending of T wave to the beginning of the P wave. The phase should always be at baseline and ion that basis it is decided whether or not the ST segment is elevated or depressed, there aren't any precise sickness conditions that elevate or depress the TP section. During the states of tachycardia, TP segment may be difficult to see it. TP segment is used as a reference in order to diagnose the PR depression and elevation. In the cases of the Tachycardia it has been reported that the P-wave may be merged with the T-wave.TP segment also represents the time when the cells of the heart muscles are electrically silent.

CHAPTER 2

LITERATURE REVIEW

ECG characteristic extraction has been studied from early time and superior strategies in addition to changes had been proposed for correct and speedy ECG feature extraction. This segmen discusses several strategies and modifications proposed earlier in literature for extracting features from ECG.

2.1 METHODS OF ECG FEATURE EXTRACTION

2.1.1 HILBERT TRANSFORM APPROACH

The ECG signal is pre-processed to do away with baseline wanders and power line interference the usage of bandpass filter. The bandpass filter is applied from high-pass filter and low-pass filters. The high-pass filter is designed deciding on cut-off frequency of zero. Five Hz, thinking about the slowest coronary heart rate, since the heart beat all through bradycardia can be round 40 beats/minute (approximately 0.6 Hz).. The QRS complex is improved to expand the QRS complex in comparison to the opposite ECG functions (P, T, and noise). The R-peak is detected by way of determining the maximum amplitude value within the diagnosed QRS complex. Given that R-wave is positive waveform and maximum top in ECG signal, the time between successive R-wave peaks is used to calculate HR (beats/minute). Hilbert model approach examined our method at the ECG signal that is obtained from MIT/BIH database. The noise because of baseline wanders, other physiological signals are removed first from the ECG signal via using low-pass and high pass filters. Later to minimize the low frequencies traits of P and T waves, to isolate and also study the predominant QRS energy centred at 10 Hz, the filtered ECG signal is processed with Hilbert Transform. In the end simple decision good judgment is used to determine the temporal location of the R-wave with a blended maximum/minimal filter. After R-Peaks are located the coronary heart rate signal is determined from the separation amongst consecutive R-Peaks and plotted.

2.1.2 FILTER BANK APPROACH

In this method the ECG signal is analysed based on frequency content. Depending upon the sharpness of the morphology of Q, R and S waves the frequency content may additionally enlarge even past 50 Hz. consequently the best manner to stumble on heartbeats is to analyze ECG sign based totally on particular sub-bands of the ECG using FIR filters in the shape of clear out financial institution, in place of considering just the output of 1 filter out which maximizes SNR of the QRS. The adaptive filter the usage of LMS filter is used to eliminate 50 Hz (60 Hz) energy line interference. In adaptive technique, typically rejection variety for a filter is less, which increases the quality and accuracy of scientific diagnoses.

2.1.3 FAST FOURIER TRANSFORM

Earlier the method used for ECG signal analysis was time domain method. But the drawback was that it was not sufficient to study all traits of ECG signal. So a new technique FFT evolved. Fourier transform is a well known technique which transforms time domain signal to frequency domain to gain the frequency coefficients. FFT is an basic transform in virtual sign processing and has diverse programs in frequency analysis, sign processing and many others. It’s far a quick and greater successful algorithm , the Discrete Fourier transform (DFT) obtains the identical effect. FFT is defined by means of the components shown:

$$XK=\sum_{n=0}^{N-1} xe^{\frac{-nk2\pi i}{n}}$$

Where k is an integer varying from 0 to N-1.var.various techniques are used for the compression of the ECG signal. One of the most essential strategies is FFT. The FFT consists of the following steps:

- obtaining an ECG pattern or enter signal.
- Compressing the input signal by means of eliminating the low-frequency components.
- Revitalization of the unique signal with the aid of the usage of inverse FFT

However the downside of FFT is that it failed to offer the facts regarding the correct vicinity of frequency components in time.

2.1.4 SHORT TERM FOURIER TRANSFORM

To triumph over this shortcoming of FFT, Dennis Gabor in 1946, first delivered the windowed-Fourier model, i.e. Short-Time Fourier transform later know as 'Gabor remodel'. STFT has each time and frequency information. it is used to decide the sinusoidal frequency and section content of the signal because it changes with time. The STFT based totally on spectrogram is an smooth and rapid approach in assessment to other time–frequency analysis equipment. It's far a easy technique of slicing the waveform of hobby into some of brief-segments. Then it analyzes each section using Fourier transform. A window feature is carried out to a phase of data, effectively setting apart that phase from the overall waveform, and Fourier transform is implemented to that section. This is called the spectrogram or short-Time Fourier remodel. For a signal x(t), the definition of STFT is given with the aid of:

$$X(\tau, f) = \int_{-T/2}^{T/2} x(t) w(t - \tau e^{-i2f\pi t}) dt$$

w(t) is a window, having period T, concentrated at time t, the Fourier transform of the windowed signal x (t) w (t - τ) is the STFT .The principle downside of STFT is that its time frequency analysisis is no longer correct. Consequently a greater premiere approach is devised to triumph over this trouble.

2.1.5 WAVELET TRANSFORM

Wavelet transform has the multiresolution belongings which gives both time and frequency facts via variable window length. In 1982 'Jean Morlet' a French geophysicist got here up with the concept of `Wavelet'. In Wavelet method a small wave and the take a look at of Wavelet method is a new technique for seismic signal look at. The wavelet's energy is focused in time and affords a tool for the analysis of temporary, nonstationary or time-varying signals. Wavelets are to be had in big numbers to be used in huge style of packages. Following capabilities make the wavelet rework useful:

- Wavelets are localized in each frequency and time.
- Non-stationary alerts along with ECG that have frequent level variations and choppy features.
- Wavelet separates the signal into multi-constitutional components.

Wavelet transforms can be categorised into two categories:

- Continuous Wavelet Transforms (CWT)

The CWT of a sign x (t) is described as:

$$w(a,b) = \int_{-x}^{x} \sqrt{a} f(t) h * \left(\frac{t-b}{a}\right) dt$$

h(t) is called mother wavelet, a is the scaling parameter in y-axis and b is the shift parameter in x-axis.

- Discrete Wavelet Transforms (DWT)

The DWT is defined as:

$$w(j,k) = \sum_j \quad \sum_k x(k) e^{-\frac{j}{2}} \psi(2^{-j} \text{ n-k})$$

Where Ψ (t) is a time function with finite energy and fast decay called the mother wavelet.

2.2 FUTURE ENHANCEMENT

The ECG is non-invasive and the record of variation of electrical signals of the human heart variability. Analysis of the electrocardiography (ECG) signal gives information about cardiac conditions, cardiovascular problems are highly essential as it can help in improving the health and living condition and proper care can be provided. The analysis derived from feature extraction can be very useful in finding out the heart diseases. The improvement of precise strategies by computerized electrocardiography (ECG) characteristic extraction is of utmost significance. Some of the features extraction methods implemented in previous research includes Discrete Wavelet Transform, Hilbert Transform, Fast Fourier transform and other methods. Every method has its own advantages and limitations. Our work primarily focuses on feature extraction from an ECG signal using FPGA platform. The future enhancement focuses on different transformation methods that provides more accuracy in feature extraction. The parameters while developing an algorithm for feature extraction of an ECG signal are simplicity of the algorithm and the accuracy of the algorithm in providing the best results in feature extraction. FPGA based ECG machines are not bulky and can be used even at homes and can be made portable. After the algorithms implemented are verified with desired accuracy The FPGA implementation can further be extended to ASIC level by making a ICs to be integrated with devices such as mobile phones, smart watches etc

CHAPTER -3

PROPOSED SOLUTION

Any kind of thorough assessment is essential and critical for the wellness of the patient. There are many benefits of ECG.

About 7.3 million deaths are caused due to the heart disease. Electrocardiography is the recorded electrical activity of the cardiac system. ECG can comfortably monitor a number of coronary heart malfunctions or disorders.

The main advantages of ECG are:

- It is a diagnostic method.
- Provides information about the chest pain, abdominal pain.
- It is an inexpensive, safe method.
- Can detect silent cardiac condition.
- Low cost and low morbility.

The main challenges for ECG devices are:

- Processing huge amount of large scale ECG data analysis in parallel.
- Real-time computation under stringent time constraint.
- ECG monitoring device that can move anywhere is wanted with better accuracy and integrates more functionality to fit in homecare services with acceptable performance.
- To embed the FPGA board to form an embedded portable system which suitable for home care and health monitoring.
- To performs ECG pre-processing and heart rate variability (HRV) feature extraction based on offline dataset using FPGA technique.

3.1 PRE-PROCESSING STAGE

The development of the FPGA based ECG system involves ECG pre-processing and ECG feature extraction, Pre-processing, which aims to improve the signal-to-noise ratio and enhance the accuracy of the analysis and measurement, includes the removal of baseline wander, high-frequency noise, and high-frequency random noise caused by power line interference .

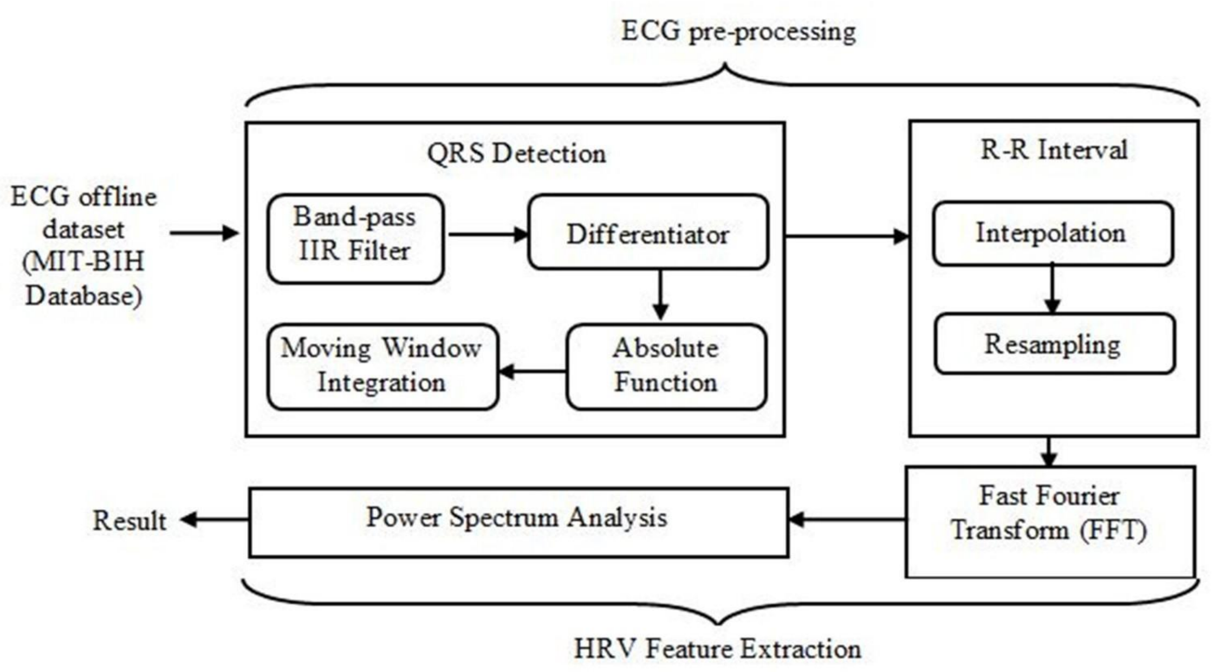

FIGURE 3.1:ECG pre-processing

3.1.1 QRS DETECTION

Previously, mainly microcomputers are being used for the processing of electrocardiography(ECG).As a matter of reality ,numerous structures have been implemented and designed to perform signal processing , 'Holter tape analysis',.An correct detection of QRS complex of the electrocardiocraphy(ECG) signal is needed for all of the programs. For an instance, coronary heart rate variability for ambulatory patients analyze the ECG in real time and whilst an sickness takes place, the monitor studies a time segment of the ordinary electrocardiography(ECG). Accurate QRS recognition capability is required for this kind of monitor. Therefore the most essential part of the ECG analysis is QRS detection

3.1.1.1 BAND PASS FILTER

ECG signal is affected by interferences such as the Power line interference, Baseline Wandering and Muscle noise. Several filters are existing which can rationally cancel out such types of noise. A band-pass filter is a device that attenuates frequencies outside that range and passes frequencies within a certain range The frequency of QRS wave lies between 5-50 Hz. Band pass filter only allows 5 to 50 Hz which is QRS wave and other frequency components (noise) will be neglected by band pass filter. A band pass filter is design with the help of high pass filter and low pass filter because the band pass filter is the combination of both filters.

Bands pass digital filter specification

ωp – normalized passband cut-off frequency;

ωs – normalized stopband cut-off frequency;

δ1 – maximum passband ripples;

δ2 – minimum stopband attentuation;

ε – passband attenuation parameter;

A – stopband attenuation parameter;

ap – maximum passband ripples **[dB]**; and

as – minimum stopband attenuation **[dB]**.

$$\delta = 1 - 10^{\frac{ap}{10}} = 1 - \frac{1}{\sqrt{1+\varepsilon^2}}$$

$$ap = -20\log\left(1-\varepsilon_p\right) = 10\log\left(1+\varepsilon^2\right)$$

Frequency normalization is defined as follows:

$$\omega_p = \frac{2\pi f}{fs}$$

fs is the sampling frequency.

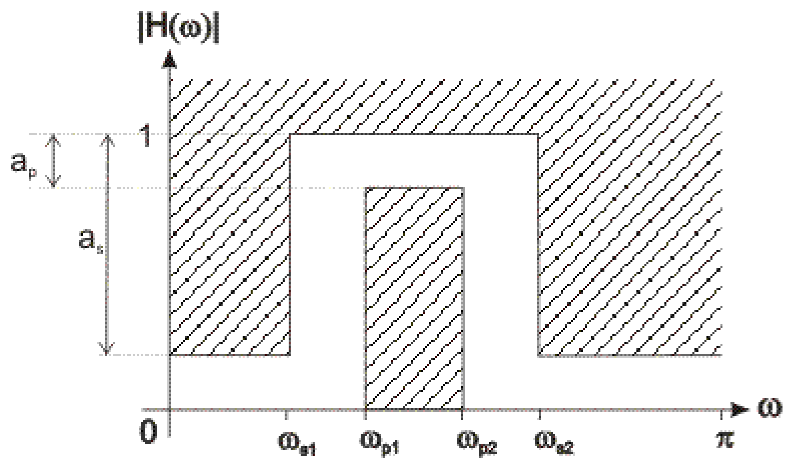

FIGURE 3.2: Band pass filter specification.

3.1.1.2 DIFFERENTIATION

Differentiation paperwork the idea of many QRS detection algorithms. Since it is largely a high-pass filter, the by-product amplifies the higher frequencies feature of the QRS complex at the same time as attenuating the lower frequencies of the P and T waves. An set of rules based on first and second derivatives firstly evolved by means of Balda et al. (1977) are used in excessive-pace evaluation of recorded electrocardiography methods:

The primary and the secondary absolute values can be calculated from the ECG signals:

$$y0(nT) = | x(nT) – x(nT – 2T) |$$

$$y_1(nT) = | x(nT) – 2x(nT – 2T) + x(nT – 4T) |$$

These two data, $y_0(nT)$ and $y_1(nT)$, are scaled and added together

$$y_2(nT) = 1.3y_0(nT) + 1.1y_1(nT)$$

The data set $y_2(nT)$ is evaluated until the threshold is achieved or exceded

$$y_2(iT) \geq 1.0$$

Once this condition is met for a data point in $y_2(iT)$, the next eight points are compared to the threshold. If six or more of these eight points meet or exceed the threshold, then the segment might be part of the QRS complex. In addition to detecting the QRS complex, this algorithm has the advantage that it produces a pulse which is proportional in width to the complex. However, a disadvantage is that it is particularly sensitive to higher-frequency noise.

3.1.1.3 MOVING WINDOW INTEGRATION

R wave slope isn't always a assured manner to locate a QRS complex. Many abnormal QRS complexes which have large amplitudes and lengthy periods (no longer very steep slopes) might not be detected by the use of statistically approximated slope of the R wave . Hence, we need to find greater information from the signal to stumble on a QRS complex.

"Transferring window integration extracts capabilities similar to the slope of the R wave. It's further carried out with following distinction equation:

$y(nT) = 1/N\ [x(nT - (N - 1)T) + x(nT - (N - 2)T) + \ldots + x(nT)]$ "

where N is the quantity of samples within the width of the moving window. The fee of this parameter need to be chosen carefully.

Width of the window have to be approximately similar to the widest viable QRS complex.The dimensions of the window is simply too complex, the combination waveform will merge the QRS and T complexes together. Then again, if dimensions of window is just too small, a QRS complex can produce various peaks at the output of the stage. The width of the window ought to be selected analytically. For a pattern rate of two hundred samples per second, the window selected for this algorithm was thirty samples wide (correspoing to a hundred and fifty ms).

3.1.2 RR INTERVAL

The aim is the detection of the R peakt because as soon as the R-peak is detected; it can be used to come across the Q and S factors without difficulty. Due to the idiosyncratic nature of the QRS complex & the unique traits of the R peak, this is effortlessly recognized even in the most distorted ECG readings. For this reason it's mainly used as the premise for ECG function identification.

3.1.2.1 INTERPOLATION

Upsampling is the system of inserting 0-valued samples between unique samples to enhance the sampling rate. (that is known as “zero-stuffing”.).Interpolation is the process of upsampling observed by using filtering. (The filtering gets rid of the undesired spectral images).As a linear system, the DSP sense of interpolation is incredibly one of a kind from the “math” feel of interpolation, but the end result is conceptually similar: to create in-between samples from the unique samples. The result is as in case you had simply originally sampled your signal on the better rate.

The number one reason to interpolate is clearly to increase the sampling rarte at the output of one device in order that another device works better if the signal is given as input.

3.1.2.2 RESAMPLING

Resampling is combining interpolation and decimation to alternate the sampling rate by using a rational aspect. Resampling is generally done to interface two systems which have one of a kind sampling rates. If the ratio of two machine’s rates happens to be an integer, decimation or interpolation may be used to alternate the sampling fee (relying on whether or not the rate is being reduced or accelerated); in any other case, interpolation and decimation have to be used collectively to exchange the charge).

As always, the Nyquist criteria should be met relative to the ensuing output sampling rate, or aliasing will end result. In other words, the output rate can't be less than two times the highest frequency of the enter signal.

3.1.3 FAST FOURIER TRANSFORM

FFT is a method used to transform analog sign to digital signal.

In FFT, the total system takes 5 steps:-

1) input signal
2) Compression (counter A)
3) Compression (counter B)
4) Recovery of the authentic sign by means of using IFFT
5) Error checking

There are two ranges for compression. In first stage of compression there is a counter A. It identifies the non-zero values of the signal earlier than compression. After compression duration of the compressed signal is as compared with the duration of the actual sign. If the duration of the compressed sign is less than the length of the real signal, then 0 padding is accomplished to make same the lengths of compressed and actual sign. Now the signal is handed through the counter B. It identifies the non-zero values after the compression of the signal. After compression duration of the compressed signal is as compared with the period of the actual signal. Now after compression if the period of the compressed sign is extra than the period of the real sign, then truncation of the signal is achieved. Now via making use of IFFT (Inverse fast Fourier transform) the unique ECG signal is recovered. The recovered sign y'(t) is compared with the original sign y(t).Error is given by

$e(t)=y(t)-y'(t)$

e(t)=error in the recovered signal

y(t)= original signal

y'(t)=recovered signal

3.1.4 POWER SPECTRUM

The ECG signal is pre-handled to get rid of benchmark meanders and electrical cable obstruction the utilization of bandpass channel The bandpass channel is connected from high-pass channel and low-pass channels. The high-pass channel is planned choosing cut-off recurrence of zero. Five Hz, pondering the slowest coronary heart rate, since the heart beat all through bradycardia can be cycle 40 pulsates/minute (roughly 0.6 Hz). The basic and powerful state of low-pass channel outlined by method for Lynn is spoken to in with the consequent switch work The QRS convoluted is enhanced to grow the QRS complex in contrast with the contrary ECG capacities (P, T, and commotion). The R-peak is distinguished by method for deciding the most extreme sufficiency esteem inside the analyzed QRS complex. given that R-wave is certain waveform and greatest best in ECG waveform, the time between progressive R-wave tops is utilized to compute HR (beats/minute).In Hilbert transform approach we inspected our strategy at the ECG flag this is acquired from MIT/BIH database. The commotion in view of benchmark meanders, other physiological signs are expelled first from the ECG waveform through low-pass and high pass filters. Later to limit the low frequencies characteristics of P and T waves, to separate and furthermore improve the dominating QRS vitality focused at.

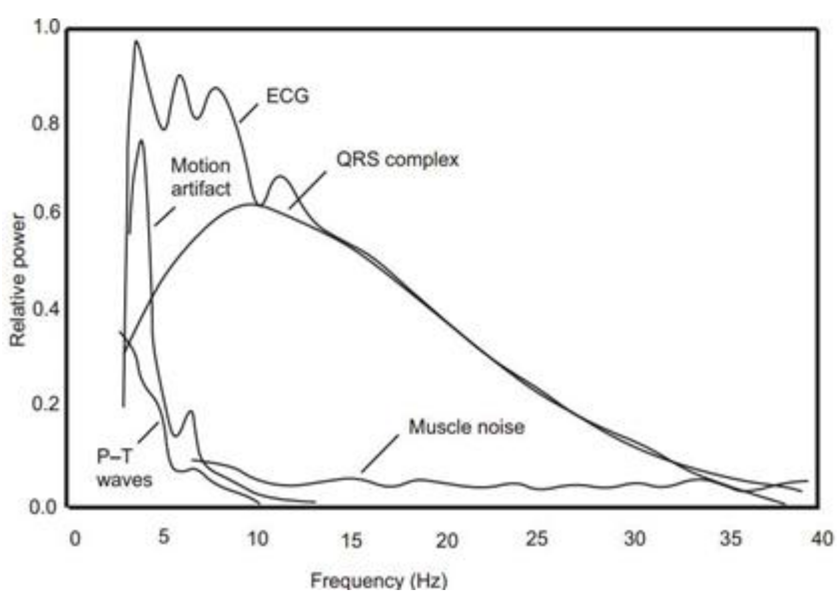

FIGURE3.3:POWER SPECTRUM

CHAPTER 4

FPGA

FGPA uses Hardware Description Language for getting specified. It is field programmable as it can be customised by the customer or the maker.

Field Programmable Gate Arrays (FPGAs) are semiconductor gadgets that are based around a framework of configurable logic blocks (CLBs) associated by means of programmable interconnects. FPGAs can be reinvented to wanted application or usefulness prerequisites subsequent to assembling. This element recognizes FPGAs from Application Specific Integrated Circuits (ASICs), which are exclusively made for particular outline errands. Although one-time programmable (OTP) FPGAs are accessible, the prevailing sorts are SRAM based which can be reinvented as the plan advances. Advantages of FPGA Technology are:

1. **Performance**:

   Exploiting equipment parallelism, FPGAs surpass the figuring energy of digital signal processors (DSPs) by breaking the worldview of successive execution and achieving more per clock cycle. BDTI, a prominent expert and benchmarking firm, released benchmarks demonstrating how FPGAs can convey ordinarily the handling power per dollar of a DSP arrangement in a few applications. Controlling information sources and yields (I/O) at the equipment level gives quicker reaction times and concentrated usefulness to nearly coordinate application prerequisites.

2. **Time to market**:

   FPGA innovation offers adaptability and quick prototyping abilities notwithstanding expanded time-to-advertise concerns. One can test a thought or idea and check it in equipment without experiencing the long creation procedure of custom ASIC plan. One would then be able to actualize incremental changes and repeat on a FPGA outline inside hours rather than weeks. Commercial off the shelf (COTS) equipment is additionally accessible with various sorts of I/O officially associated with a client programmable FPGA chip. The developing accessibility of abnormal state programming devices diminishes the expectation to absorb information with layers of reflection and regularly offers important IP centres (prebuilt capacities) for cutting edge control and flag handling.

3. **Cost**:

   The nonrecurring building (NRE) cost of custom ASIC plan far surpasses that of FPGA-based equipment arrangements. The expansive beginning interest in ASICs is anything but difficult to legitimize for OEMs shipping a huge number of chips every year, except numerous end clients require custom equipment usefulness for the tens to several frameworks being developed. The very idea of programmable silicon implies you have no creation costs or long lead times for gathering. Since framework necessities frequently change after some time, the cost of rolling out incremental improvements to FPGA plans is insignificant when contrasted with the substantial cost of respinning an ASIC.

4. **Reliability**:

   While programming apparatuses give the programming condition, FPGA hardware is really a "hard" usage of program execution. Processor-based frameworks frequently include a few layers of deliberation to help plan assignments and offer assets among numerous procedures. The driver layer controls equipment assets and the OS oversees memory and processor data transfer capacity. For any given processor center, just a single direction can execute at once, and processor-based frameworks are constantly in danger of time-basic errands pre-empting each other. FPGAs, which don't utilize OSs, limit dependability worries with genuine parallel execution and deterministic equipment committed to each errand."

4.1 USES OF FPGA:

FPGA is generally used for solving the computable data related issues. There are certain uses of the FGPA:

- Audio
- Aerospace Defence
- Industrial
- Automotive
- Medical
- Bioinformatics
- Broadcasts
- Video and Image Processing
- Security
- Wired Communications
- Wireless Communications

The leading manufacturer of the FGPA is now Intel. In 2016 Xilinx and Altera were the leading dealers. Others are Microsemi, SiliconBlue Technologies, Atmel, Acronix etc.

4.2 DESCRIPTION OF THE DEVICE

"Straightforward 6 FPGA Electrical Characteristics Spartan®-6 LX and LXT FPGAs are accessible in different speed grades, with - 3 having the most elevated execution. The DC and AC electrical parameters of the Automotive XA Spartan-6 FPGAs and Defense-review Spartan-6Q FPGAs gadgets are proportionate to the business determinations aside from where noted. The planning qualities of the business (XC) - 2 speed review modern gadget are the same with respect to a - 2 speed review business gadget. The - 2Q and - 3Q speed grades are solely for the extended (Q) temperature go. The planning attributes are identical to those appeared for the - 2 and - 3 speed grades for the Automotive and Defense-review gadgets. Austere 6 FPGA DC and AC qualities are determined for business (C), modern (I), and extended (Q) temperature ranges. Just chose speed grades as well as gadgets may be accessible in the modern or extended temperature ranges for Automotive and Defense-review gadgets. References to gadget names allude to every single accessible variety of that part number (for instance, LX75 could indicate XC6SLX75, XA6SLX75, or XQ6SLX75). The Spartan-6 FPGA - 3N speed review assigns gadgets that don't bolster MCB usefulness. All supply voltage and intersection temperature particulars are illustrative of most pessimistic scenario conditions. The parameters included are regular to well known outlines and normal applications."

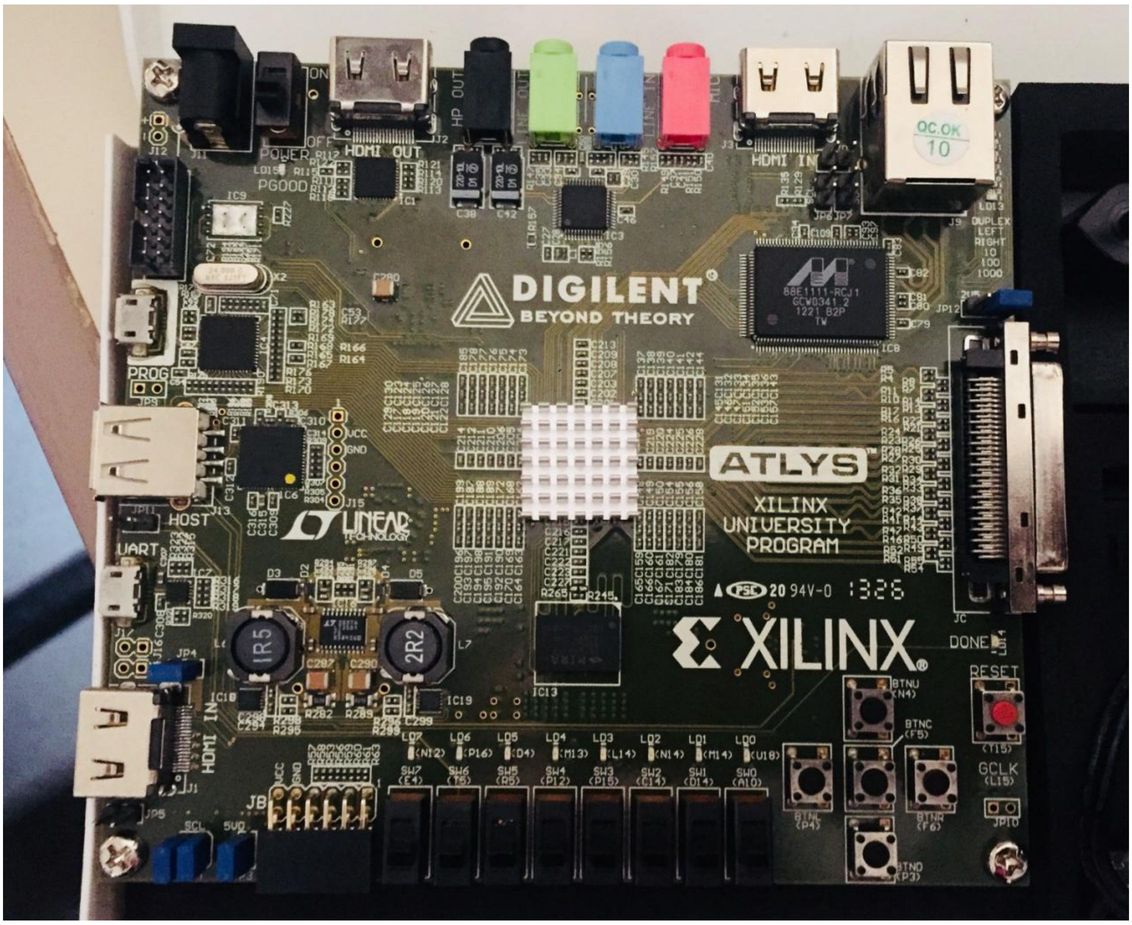

FIGURE 4.1 –XILINX SPARTAN-6 XC6SLX45 FPGA KIT

CHAPTER -5

IMPLEMENTATION OF IIR FILTER

A filter is used to remove the undesirable signals or the noise of the signal. In naval there is requirement to remove the unwanted portion of the underwater acoustic signals. Digital filters are basically of two types:

1) FIR (Finite Impulse Response) filter and
2) IIR (Infinite Impulse Response) filter.

LTI system's impulse response, which do not reach zero past a certain point and continues. Such a response is called as Infinite Impulse Response. IIR filters are better to implement than FIR filters to meet the specifications like pass band, stop band etc... Computational time is saved by using digital IIR filters which is a large factor. IIR filters give the output such that the input is deformed without filter frequency which by means called as non linear phase characteristic. These filters are not believed to be stable when the output is mainly dependent on frequency domain rather than time domain. IIR filters are computationally more efficient than FIR filters as they require as they require fewer coefficients due to the usage of poles and feedback.

Generalized equation of IIR filter is

$$y[n] = \sum_{k=0}^{N} b[k]x[n-k] + \sum_{k=1}^{M} a[k]y[n-k]$$

$$H(z) = \frac{b_0 + b_1 + K + b_n z^{-n}}{1 + a_1 z^{-1} + k + a_M Z^{-M}}$$

$$= \frac{\sum_{k=0}^{N} b_k \, z^{-k}}{1 + \sum_{k=1}^{M} a_k z^{-k}}$$

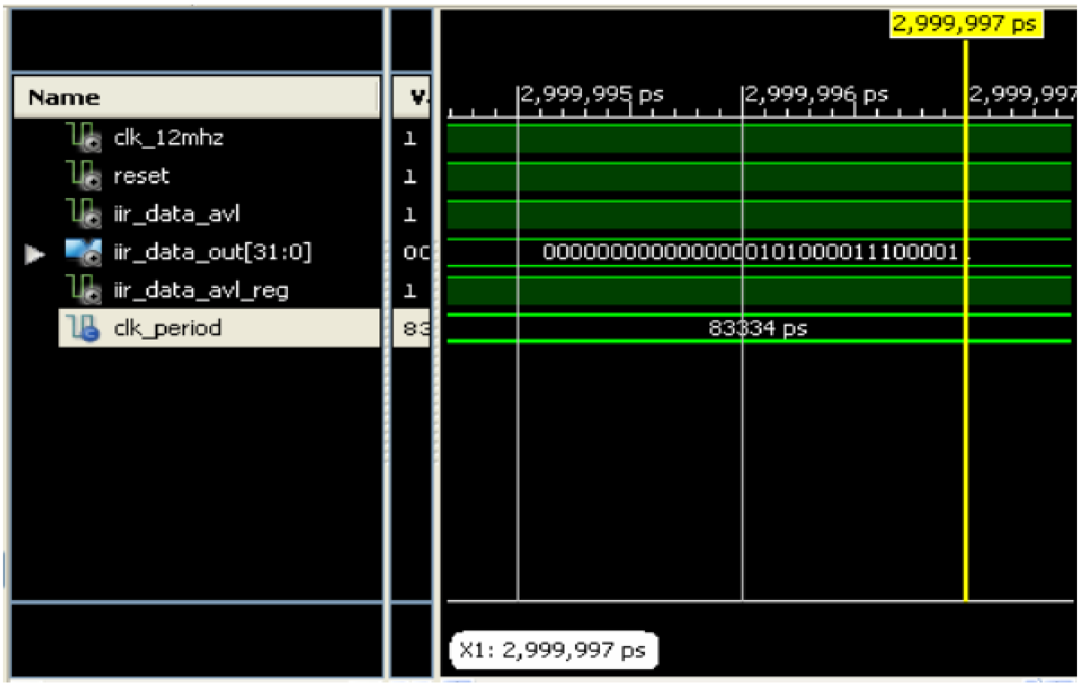

FIGURE5.1:RESULT OF IIR BAND PASS FILTER

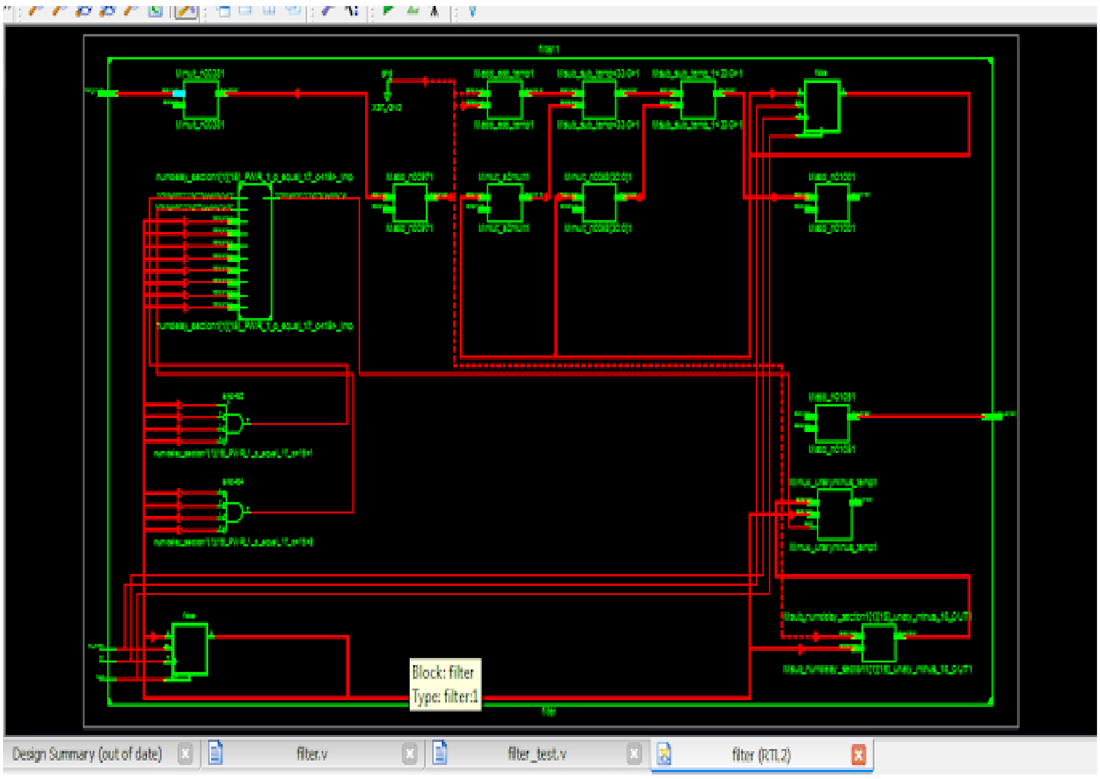

FIGURE 5.2:SCHEMATIC DIAGRAM OF BAND PASS FILTER

5.1 FILTER TYPES

Basically filter is process which can be devised that helps in removing the unwanted noises and unwanted components of the signal. The main feature of filtering which is a class of signal processing is partial and full compression of some part of the signal and mostly, this implies on removal of some frequencies of the signal to further suppress the unwanted signals and to reduce the noise components from the signal.Filters no longer exclusively act in the frequency domain; mainly within the subject of signal processing many other targets of firing exists.

Filters available

5.1.1SAVIZKY-GOLAY FILTER

The main purpose of the savizky – golay filter, which is a digital filter, is the smoothing of the digital data points , i.e to achieve high signal noise ratio without changing the input signal. A process called convolution can be applied to achieve high signal to noise ratio,this can be done by filtering of adjacent data points of consecutive datasets with a low-degree polynomial by linear least squares method when the spacing of the datasets is uniform , “convolution coefficients” gives an analysed solution of the least square method equations ,these equations is valid for all the dataset available , to give estimation of the smoothened signal at the central point of each sub set. This method is purely based on precise solutions, was popularized by ‘Abraham Savitzky’ and ‘Marcel Je Golay’ who published tables of convolution coefficients for various polynomials and subset size . Some errors in the table have being corrected. The method has being extended for the treatment of two and three dimentional data.

5.1.2 FIR FILTER

The FIR (finite impulse response)filter is a filter of fixed duration whose impulse response tends to zero the in defined duration. The FIR filter is different from IIR filter as it has a internal feed back system and may continue to respond infinitely.

The response of the FIR filter of nth discrete time last for exactly N+1 samples of the filter .

FIR filter can be analogue or digital or discrete time or continuous time .

5.1.3 MEDIAN FILTER

Noise reduction in an image or signal is highly demandable in the fileld of signal processing . A nonlinear digital filtering technique is median filter,which is mainly used to remove the unwanted noise from the signal. This reduction in noise is basically done for better analysis of the input signal (for example, edge detection on an image.)Digital image processing are excessively using median filter as in some conditions they preserve the edges while removing the noise from the signal.

ALGORITHM DESCRIPTION

The median filter works on the idea of running through the input signal one by one ,replacing the entry of the present window with the entry of the adjacent entry . The portion of the signal selected is called ‘window’ which slides through the entire input signal. For ID signals, the most obvious window is just the first few preceding and following entries, whereas for 2D (or higher-dimensional)signals such as images, more complex window patterns are possible (such as “box” or “cross” patterns).Note that if the window has an odd number of entries, then the median is simple of define: it is just the middle value after all the entries in the window are sorted numerically. For an even number of entries, there is more than one possible median, see median for more details .

5.1.4 GAUSSIAN FILTER

In signal processing and electronics , a filter is defined as Gaussian filter if the impulse response is Gaussian or approximation of gaussian . While minimizing the rise and fall time,the Gaussian filter shows the characteristics of overshooting to a step function input. This action is slackly connected to the fact that the Gaussian filter has the least possible group delay. As the sinc is the ideal frequency domain filter, Gaussian filter is the ideal time domain filter.

The characteristics shown by the Gaussian filter are extremely helpful in areas such as oscilloscopes and digital telecommunication system .Precisely, a Weierstrass transform is defined as the modification of the input signal with convolution with a Gaussian function.

5.1.5 BUTTERWORTH FILTER

In signal processing ,butterworth filter can be described as a filter made to have a flat response of frequency as possible in the band pass . Maximally flat magnitude is another name of the Butterworth filter. It was found by British engineer and physicist 'Stephen Butterworth' in the year 1930, in his paper entitled "on the Theory of Filter Amplifiers"

As one of the best filters, the Butterworth filter has the capability of solving the most difficult mathematical problems . Due to limitations of the theory then in use, the design of the filter required a considerable amount of designer experience. The paper on butterworth filter stated :

"An ideal electrical filter should not only completely reject the unwanted frequencies but should also have uniform sensitivity for the wanted frequencies".

Such an excellent filter cannot be achieved but Butterworth confirmed that successively closer approximation was obtained with increasing wide variety of filters factors of proper values. At the time, filters generated huge ripple in the pass band, and the selection of component values became relatively interactive.

A low pass filter can be made whose cut off frequency can be up to 1 radian per second and the frequency response was given by:

$$G(W) = \sqrt{\frac{1}{1+\omega^{2N}}}$$

ω = angular frequency in radians per second and

n = number of poles in the filter-equal to the number of reactive elements in a passive filter.

If ω =1, the amplitude response of butterworth filter in the passband is $1/\sqrt{2}$ = .707 which is half power or -3db.

CHAPTER -6

CONCLUSION

There is no doubt that ECG has contributed to the Medical field. The pioneers in developing ECG technology were Alexander Moorhead, Augustus Waller, William Enthoven, Taro Takemi etc. ECG with its higher capacity to measure and diagnose conditions like myocardial infarction, pulmonary embolism, hyperaemia, cardiac stress testing, Biotelemetry has revolutionised the medical field and has opened gateways for more and more development.

The system proposed in this chapter periodically analysis the ECG signal of the old patients with cardiac problems. During emergency, an alarm can be sent to the hospitals and relatives so that speedy treatment could be given to the patients .Hence ,this project is will help in diagnosis and will eliminate the need for transportation at the eleventh hour. It also helps he patient to calm down and be relaxed even when they are alone. This project "Implementation of heart rate variability analysis algorithm using FPGA platform "will help the people with heart diseases and analysis can be done quickly.

The primary limitation of this system is the time taking embedded software execution reasons the system performance bottleneck.

Future enhancements are as follows: -

a) The computation performance is boosted due to hardware accelerator.
b) Online monitoring can be appilied to the ECG signal acquired
c) Integrates latest set of rules for cardiac problem detection as a selection aid device.

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