A Review of Significant Role of Electrocardiogram Signal and Field Programmable Gate Arrays

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Abstract - This paper presented the review of electrocardiogram and FPGA of digital filtrations. Electrocardiogram (ECG) signals are frequently distorted by electrical and mechanical noise including power line interference, electrode movement, motion artifacts, and so on. Doctors need a clear ECG signal to make an accurate diagnosis. Filtering techniques to remove ECG signal noise using IIR & FIR digital filters have significant advantages over the former. Furthermore, a general-purpose multiplier takes up a lot of space on FPGAs, and its full flexibility isn't always needed. Silicon devices could be programmed in the field to become almost any type of digital circuit or system. Faster time-to-market and lower cost are two advantages of FPGAs over ASICs, which typically require a significant amount of money and time to produce the first device.

Keywords - ECG, Field Programmable Gate Arrays, IIR, FIR, digital filters

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INTRODUCTION

An electrocardiogram (ECG) is a bioelectric signal that measures the heart's electrical activity over time. Heart disease research relies heavily on this technique. Heart disease is a major factor in the rising death toll in the human population. The unexpected death of a cardiac patient can be prevented if the condition is diagnosed and treated early enough. Heart illness can be diagnosed with the aid of an ECG. The electrical activity of the heart is recorded by placing electrodes on the skin. In most cases, the ECG signal's amplitude is in the 0.1 mV to 3 mV range [Seema et al, 2011]. ECG signals have a frequency range of 0.05 to 100 Hz. The P wave, QRS complex, & T wave combine to generate an ECG signal, as depicted in figure 1.1. In 59 to 70 percent of EGCs, a faint U wave can be seen. Left & right atria activation can be seen on the P wave. The depolarization of the left & right ventricles is represented by the QRS complex. Repolarization of the ventricles is depicted by the T wave complex.

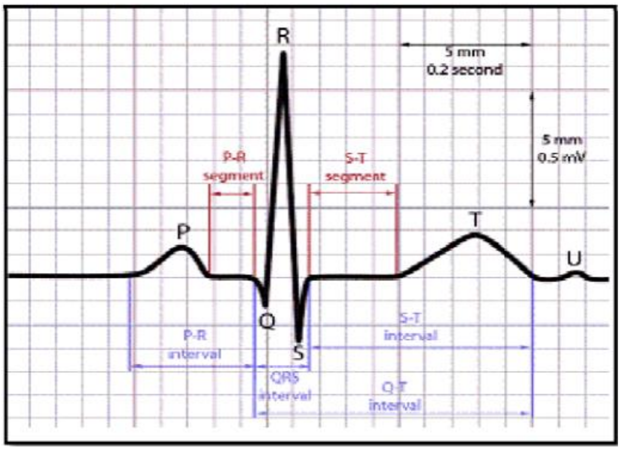

Figure 1: Normal ECG Signal

The varying values of these markers point to a heart condition. Arrhythmia is an abnormal heartbeat, and some arrhythmias can be exceedingly dangerous for patients.. AC interferences, loose electrode connections, the malfunction of the machine, and the patient's motions, such as respiration, can cause the ECG signal to be corrupted. Medical monitoring devices provide a thorough comprehension of the biomedical signal recording & demand more exact data for the diagnostic. When a patient is being diagnosed, it is difficult to achieve an accurate ECG signal recording result [Aleen 1994]. Any surrounding machinery's electromagnetic field has the potential to contaminate the ECG signal [Wei 2003]. The output of an ECG signal could damaged

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when a patient is being diagnosed in a hospital or someplace else by this 50-60 Hz noise. Because of interference noise from the power source or the environment, it is impossible to get an exact reading from an ECG signal recording. There are groups of sodium (Na+) & potassium (k+) ions in the blood that form an electrical ECG signal.

A recording bandwidth of 0.1 to 120 Hz is required for the ECG signal, which is normally in the 2 mV range. Electrodes attached to the surface of the human body can capture the ECG signal, which is created by the heart's rhythmic contractions. Signals gathered at each electrode and subsequently recorded. There are 12 different leads I, II, III, AVR, AVL, & AVH, while the chest leads are V1, V2, V3, V4, V5, and V6. Pictured in figure 1.2 is the original ECG signal downloaded from the MIT-BIH database (Massachusetts Institute of Technology-Beth Israel Hospital).

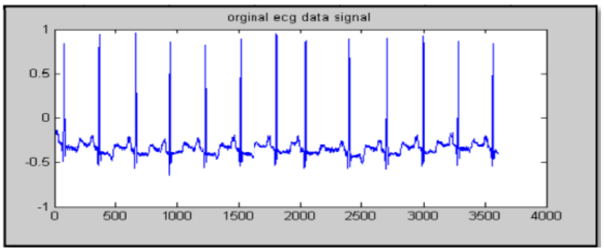

Figure 2: ECG data signal for record No. 222 MIT-BIH database

RLS algorithm, LMS & NLMS algorithm and SSRLS algorithm of adaptive filtering are some of the strategies being used by researchers to remove noises. Chebyshev filters, IIR filters and Zero phase filtering are also being used to remove noise. In this study, nine window approaches of the FIR (Finite Impulse Response) filter were utilized to reduce the noise of distinct ECG data signals. Neural networks trained for window-based FIR filters aren't mentioned anywhere in the survey.

DIGITAL FILTERS

Digital filters play a critical role in signal processing, removing unwanted signals like noise or extracting the important parts of signals that fall within a certain frequency range. To reduce noise in the ECG signal, a variety of techniques are available, including the Infinite Impulse Response (IIR) & FIR filters, each with their own set of pros & cons. The best solution for noise reduction is a digital filter, which is best suited for ECG analysis because it improves the ECG signal's quality. Thus, the design cycle of digital filters have to reduced. At each intermediate step in the transformation process, they perform noiseless mathematical functions without causing any interference. Filter coefficient quantization error is less of an issue with FIR filters because they are simple to design and easy to achieve linear phase performance. This makes FIR filters a popular choice for digital signal processing applications such as digital audio & image processing and data transmission. Various filter types, such as low-pass, high-pass, band-pass, and band-stop filters, are employed in the solution of various design challenges. Direct, cascade, polyphase, lattice, or other major forms of FIR filter structure can all be considered basic structures.

An IIR filter is a type of recursive filter in which the current output is dependent on both previous outputs and the inputs it received. Many times, they can be a lot better than a FIR filter when it comes to efficiency in terms of order. Because of their lower latency & closer resemblance to analogue circuits, IIR filters produce better magnitude responses with fewer coefficients. It is difficult to implement IIR filters in a pipelined design due to the fact that feedback could incorporate instability, limit cycles, non-linear phase response, and other drawbacks. The following Eqn1.1. could be used to depict the operation of a FIR filter.

$$y(n) = \sum_{k=0}^{M-1} h_k x(n-k) \qquad (1.1)$$

Hkare are the filter coefficients, or the length of M is the filter length.

The Eqn. is the simplest form of IIR operation. 1.2

$$y(n) = -\sum_{k=1}^{N} a_k y(n-k) + \sum_{k=0}^{M-1} b_k x(n-k) \quad (1.2)$$

Where M is the maximum input delay, hkare the numerator coefficients; N is the maximum output delay, and ak are the denominator coefficients.

From Eqn. 1.1 and 1.2 , computation of y[n] involves calculation of y[n-1], y[n-2],.....y[n-N] and x[n], x[n-1], x[n-2],......x[n-M] hence there is a requirement of basic elements like delay or storage, multipliers and adders (subtract is measured as addition). As a result, different structures for discrete-time LTI systems could be realised by arranging y[n] computations in various ways to obtain the same difference equation.

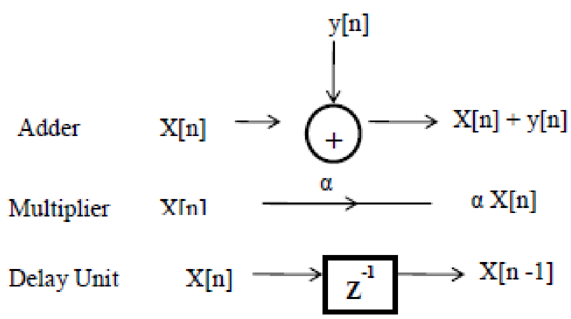

Figure 3: Basic operations in block diagram

A signal flow graph or a block diagram can be utilized to represent an implementation. Figure 1.3 depicts the block diagram operations required to make digital filters. There are many ways to reduce the number of multipliers in a system, but one of the most common is to use an adder to handle multiple sequences. Digital implementation of the Delay Unit

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could be achieved by provide a storage register for each delay unit. The Direct Form-I, II, Cascade Form, & Parallel Form are structures used in IIR filters, whereas the Direct Form-I & II are structures used in FIR filters. There are a variety of digital filter structures that has to utilize to remove various types of noise.

A parallel-pipelined architecture is utilized to execute filters based on FPGAs & ASICs, which improves performance. Because of the higher sampling rates and lower costs offered by VLSI implementations of digital filters, they can be used in FPGAs or other VLSI. Because digital filters can achieve a better signal-to-noise ratio than analogue filters and because analogue filters introduce more noise into the signal at each stage, digital filters are broadly utilized in the electronics industry. Filters that remove noise, shape the spectrum, & minimise inter-symbol interference in communication systems have emerged as a viable option. Design engineers can achieve performance levels that are difficult to achieve using an analogue filter because these filters can be precisely reproduced. As opposed to IIR filters, FIR filters are more commonly found in digital signal processing (DSP).

For long-term health monitoring, patients cannot use traditional ECG diagnostic products from various companies because they are cumbersome & inconvenient. Portable biomedical applications require a lot of power to run efficiently. In order to create a flexible electrocardiogram system with an improved filtering technique, the emphasis is on designing systems with embedded circuits & available technologies. ECG currently lacks flexibility & neither compatible with PC and communications standards nor can they be easily upgraded. As if that wasn't bad enough, owning one for personal utilize at home is prohibitively expensive. A medical professional or patient-friendly ECG monitoring system will have these features: integrated designs, portability and flexibility; wireless communications; comfort & ease of use. Some ECG monitoring systems use microcontrollers, while others use DSPs and medical development kits that include electrocardiograms and oximeters are common. Innovative devices such as FPGAs combine the advantages of software and hardware by limiting their clock rate. Comparatively speaking, FPGAs are low-cost devices that combine high performance with flexibility, reconfigurability & programmability as well as high reliability and high logic density. Many times, an FPGA based system can be reconfigured, as computations are pre-programmed but not permanently frozen at a time of manufacturing.

LITERATURE REVIEW

Siho Shin et al. (2020) It is critical to get immediate medical attention if you suspect you have heart disease and have any symptoms. Patients who are required to evaluate their health on a regular basis may face a fatal challenge if they use machine learning to detect cardiac disease. We present an arrhythmia diagnosis ensemble method based on MobileNet that can be used quickly and conveniently on the go. In order to improve the accuracy of a short-term ECG signal, the matching pursuit algorithm was used to enhance the ECG signal. MobileNetV2 &BiLSTM were used to classify the arrhythmia data in an ensemble classifier. An accuracy of 91.7 percent was reached by applying this algorithm to classify the data. A confusion matrix and a receiver operating characteristic curve were used to gauge the algorithm's efficiency. Sensitivity (0.92) was followed by specificity (0.91), precision (0.92), and F1 score (0.92). Health management for busy persons is made easier by the proposed algorithm's lack of long-term ECG signal measurement. In addition, parameters are exchanged when data is learned, increasing the system's security. In addition, the suggested approach can be used in mobile healthcare, object identification, text recognition, & authentication because of its lightweight deep-learning architecture.

BinduSwethaPasuluri et al. (2020) We present a first-order analogue LPF depend on a easy current mirror OTA and a digitalized LPF with Vedic multipliers for biomedical applications in this article. For ECG signal capture, the analogue filter can be used in the weak inversion area with minimal power consumption. With the use of mirror-based OTA, this filter may be implemented with a smaller number of available components and a more efficient design. The 45nm CMOS technology was used to develop and model the filter. FIR filter implementation using an improved Nikhilam Sutra Multiplier is also a big advancement in this work. In adding, the Kongestone adder was likely used to boost speed & performance. The revised FIR filter architecture was developed & generated using Xilinx FPGA Spartan 6 and Xilinx ISE in order to achieve the best results. According to calculations, the analogue filter has a bandwidth of 100 Hz and a power consumption of 0.276,W. The suggested Digitized FIR filter design is at least 20% faster than conventional multiplier-based LPFs, according to simulation results. Both the digital & analogue filters provided here have increased performance when compared to previous designs.

Hussein et al. (2020) Applications of digital filters have become increasingly commonplace in modern telecommunications systems & signal processing. Filtering could utilized to eliminate the many disturbances and disruptions that occur in the actual world, ensuring that the signal is clear and unaffected by them. An overshoot of the signal can occur in a digital filter at some point in time. Changing the filter's coefficients can alter the cutoff frequency, causing a transient to occur. In this study, we present a compensation method based on an nth-order digital Butterworth LPF filter for eliminating this overshoot. In the suggested method, various filtering procedures are utilized to the input signal to eliminate an overshoot and produce a clear real signal with minimal or no disturbance. The transient process arising from the filter restructure was explored & formulas for compensating for this transient process were tested to use the MATLAB program. Such compensation was found to have a positive effect on the transition process, according to the study results. The filter's reduction in frequency is dependent on the filter's order, adjustment coefficient, & adjustment time (for the periodic signal).

Ahmed S et al. (2020) In order to acquire trustworthy and accurate clinical interpretations for heart problems,ECG signals are particularly susceptible to disruptions induced by noise and artifact sources. ISLR & ALDKRLS algorithms are introduced in this work for the first time in this paper, and they are used to suppress white/colored noises and other artifact sources, respectively. Artifact components are suppressed using ALDKRLS in the initial stage and noise sources are eliminated using ISLR in the second stage. Real ECG data is used to illustrate the strength of the future multi-stage filter by removing noise & artifact components separately and simultaneously. Experiments show that the proposed framework is extremely accurate in removing interference sources while preserving the basic and vital aspects of the original ECG data. A novel proficient ECG multi-class categorization system before & after suppress noise & artifact interferences is evaluated as a practical implementation of the framework proposed. ECG diagnosis findings reveal that the proposed framework is able to efficiently remove noise & artifact components while keeping the fundamental properties of the ECG signal that distinguishes between cardiac diseases.

Yakut et al. (2020) Cardiac arrhythmias can create life-threatening health complications. ECG signal analysis is a critical diagnostic tool for evaluating heart function in clinical research and illness diagnosis. ECG signal analysis was subject of numerous Soft Computing approaches & techniques up to this point. An EL based technique that automatically diagnoses ECG signal arrhythmias based on the category-based & patient-based estimate plan has been developed in this study. It was necessary to remove the ECG signal's baseline wander using a two-stage median filter. With the newly developed QRS complex detection approach, we were able to pin down the ECG signal's fiducial points' locations. Four different feature extraction strategies were used in this investigation. The Power Spectral Density has been considered as a novel feature extraction technique. In order to create hybrid sub-feature sets, a feature selection advance base on Wrappers was used. A stacking approach has been used to implement Ensemble Learning (EL). Random Forest (RF), Multi-layer Perceptron (MLP). Linear Regression (LR), the meta learner. The suggested novel technique lies on EL had average performance values of 99.88 percent accuracy, 99.08 percent sensitivity, 99.94 percent specificity, and 99.08 percent positive predictivity (+P) for the category-based classification of arrhythmic heartbeats. The average accuracy, sensitivity, specificity & positive predictivity (+P) for patient-based arrhythmic heartbeat categorization were 99.72%, 99.30%, 99.83%, and 99.30%, respectively. Thus, it can be accomplished that the future strategy outperforms similar research in the research in terms of performance results.

K.Vijetha **et al. (2020)** DA architecture is used in this research to construct a low-complexity pipelined adaptive FIR filter for signal processing application. Adaptive filters, in general, take up more space & power since they employ memory to generate partial products (PP). As an alternative to conventional adders, we use compressor adders in the adaptive filter topologies instead of reducing registers in the filters as part of our pipeline approach. Adaptive filters could made smaller and use less power if one of these two approaches is adopted. Verilog HDL language is used to code the design, which is then synthesized in the Synapsis design compiler tool using SAED 90 nm technology to find the area (A), power (P), sampling period (S), and other design parameters (PDP). With the suggested adaptive filter, higher-order filters could design and implemented more quickly and with less complexity than previous designs. In comparison to the two memories-based existing architecture, our proposed solution will take up 30% less space. As an added benefit, the block-based adaptive filters use 25% less power. When compared to current designs, the suggested design's ADP and PDP are incredibly low. Adaptive decision feedback equalizers for reducing signal disturbances & inter-symbol interference, hearing aids, ECG signal analysis, and software defined radio are all examples of signal processing applications that can benefit from this approach.

Aya N. Elbedwehy et al. (2020) Noises includes baseline wander, channel noise, Electromyogram (EMG) noise, & power line interference affect ECG readings, which are then distorted (PLI). Diagnoses are challenging because of these noises. A low-cost, portable device that can eliminate noise from corrupted ECG data with good performance, speed & privacy has been developed in this study.' To begin, a high-performance SNRC architecture is used to clear the distorted ECG signals. Second, we use a portable, low-cost FPGA device to put our method into action, allowing us to achieve both fast speed and anonymity. The normal EMG & PLI noises are simulated in this manuscript. The output SNR improvement (SNRimp), MSE, & the percentage root mean square difference (RMSD) are the measures we utilize to evaluate our approach (PRD). The MIT-BIH arrhythmia database is used to gather the information. AnSNRimp of 15.8 and a PRD of 24.6 in the EMG noise and an SNRimp of

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25.7 in the PLI noise may be achieved with an input SNR of 0dB. The suggested system's advantages are demonstrated through comparisons with related works.

ManoharanTamilselvi et al. (2020) The most critical signal in biomedical signal processing is the ECG (Electrocardiogram) signal, which is utilized to assess the health of heart function. Modern ECG signal processors are more compact and smaller in size. Algorithm implementation in hardware is a difficult task. Preprocessing, extraction, & diagnostics, among other functions, must be implemented in hardware. Different sorts of noise will taint the ECG signal. Filtering out the noise and extracting medical information is the goal of the filter that will be applied. Based on swarm optimization approaches, adaptive filtering for a biomedical system on chip architecture has been demonstrated in this article. The proposed technique was tested on a variety of hardware platforms and the results are analyzed. Filters have a linear phase and a high rejection rate. The implementation was carried out using FPGAs (field programmable gate arrays). For ECG signal preprocessing & extraction, these adaptive filters are part of the filter circuits. Programmable Power Technology was implemented utilizing Intel Altera's Quartus software.

F. Karataş et al. (2020) ECG signals from vital signs such as sinus tachycardia, supraventricular & PVCs, atrial fibrillation & ventricular tachycardia were mathematically designed, modeled on an FPGA using VHDL & Xilinx-Vivado software. The results of this study show that these eight arrhythmic ECG signals can be reliably simulated on an FPGA. An ECG signal's time and amplitude values were taken into account when creating the mathematical extrapolation, which was done in accordance with the literature and after analyzing a large number of ECG signals from the Physiobank ATM section of the arrhythmia database at the MIT. The Zynq-7000 XC7Z020 FPGA chip was used to create these signals for use in biomedical calibration and ECG simulators. An AD9767 DAC module was used to mimic the ECG signals, and a four-channel oscilloscope was used to monitor the real-time data. The findings of the FPGA-based ECG signal design were compared to those of Matlab-based ECG signals as a point of comparison. FPGA chip resource consumption and test results are shown, as well as operating frequencies for each signal and system. The MSE (mean squared error) values for each signal are also shown. This system can run at a maximum speed of 651.827 MHz. An FPGA-based ECG signal production system that may be utilized in ECG simulators has been demonstrated in this work. The created system is safe to use.

Senthil Vadivu et al (2020) ECG signal extraction from non-invasive abdomen ECG signals is an important clinical practice for monitoring a fetus' health. ECG readings from a fetus can reveal information about the fetus' cardiac development & health. It is still a challenge to extracting the ECG of the fetus from an abdominal ECG signal. Maternal ECG signals that have been corrupted by excessive amplitude are the main culprit here, as are fetal ECG signals that have been superimposed onto maternal ECG signals, as well as motion and electromyography aberrations in the fetal ECG signal. In this study, a unique CGAN is used to extract the fetal ECG signal from the ECG data. Pregnant ECG data from non-invasive abdominal ECG signals were successfully categorized using the suggested classification algorithm. When compared to other traditional fetal ECG extraction methods such singular value decomposition, periodic component analysis, & Adaptive neuro-fuzzy inference system, the pragmatically results show that the suggested network model is more sensitive, specific, and accurate.

Ashish Kumar et al. (2019) in current implantable cardiac pacemakers, low-power and high-performance digital ECG detectors have become a necessity. This study proposes a fractional operator-based digital ECG detector for current pacemakers. Traditional thresholding is replaced by adaptive slope prediction thresholds for ECG peaks detection. To construct an effective fractional operator for ECG denoising, a stochastic search-based approach, called cuckoo, is used. The future adaptive slope prediction threshold has been found to improve the detection of QRS complexes. The future ECG detector achieves a low detection error rate (DER) of 0.01 percent to 0.56 percent, positive predictivity (P+) of 99.32 percent to 99.98 percent, sensitivity (Se) of 99.45 percent to 99.98 percent, and detection accuracy (Acc) of 99.43 percent to 99.96 percent for different databases. As part of the LWDF fractional order operator, a minimum number of multipliers is required for its structural realization.

Sood, Meenakshi, et al. (2018) Biomedical systems are composed of an energy source, signal processing & conditioning, and the transmission of the signals. This paper reviews these components. These blocks were created using a variety of optimization strategies in order to maximize speed, minimize footprint, and use the least amount of energy possible. Some of the most common methods include: (a) using energy harvesting measures to extend device life; (b) reducing delay to increase operating frequency, (c) reducing the amount of data stored, and (d) boosting data rate transmission with reduced power consumption. There are numerous dissimilar approaches that could utilize to improve the performance of a device. Input was critical to the development of these high-performing systems. Different low pass IIR filter approximation methods to reduce Electromyography noise from ECG input signal are also presented in this research. We used the MIT-BIH Arrhythmia database for this purpose. Signal-to-noise ratio and power spectral density have been calculated. The Elliptic filter was determined to be the best low-pass IIR filter for removing this type of noise when compared to other low-pass IIR filters.

CONCLUSION

The ECG is a piece of medical equipment that measures the electrical behavior of heartbeats by sending a pulse wave from the heart to the muscles that squeeze & pump blood into the organ. The ECG is recorded by the ECG machine. Doctors base their decisions on the characteristics of the ECG signal. Electronics systems of the future must be able to operate at high speeds & respond quickly. The use of FPGA design technology for evaluate & implement signal processing algorithms has grown in popularity. However, the FPGA implementation has its own set of issues, including cost, power, area & speed. Thus, the design cycle of digital filters could reduced. At each intermediate step in the transformation process, they perform noiseless mathematical operations without causing any interference. Numerous digital signal processing fields, including communications, digital audio, image processing, data transmission, biomedicine, and other fields, rely on FIR filters for their signal processing needs.

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