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COMPARISON OF FIR AND IIR FILTERS USING ECG SIGNAL WITH DIFFERENT SAMPLING FREQUENCIES

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ABSTRACT

Over the last few decades, the use of digital signal processing has become increasingly popular in the digital world. This is mainly due to its ability to efficiently transform digital and/or analog signals, thereby reducing the cost associated with design and implementation. Filtering is typically used to remove noise from the desired signal. In signal processing, there are two main types of filters: finite impulse response (FIR) filters and infinite impulse response (IIR) filters. FIR filters have an impulse response of finite duration, meaning it settles to zero in a finite amount of time. On the other hand, IIR filters have an impulse response of infinite duration due to the use of feedback from previous output values, allowing them to achieve the same filtering characteristic as FIR filters with less memory and calculations.The goal of this project is to utilize various window techniques to implement minimum order FIR and IIR filters that meet specific specifications for Electrocardiogram (ECG) signals. By comparing the performance of both FIR and IIR digital filters, the project aims to assess their effectiveness in achieving a linear phase response and passing signals without phase distortion.

Keywords: Electrocardiogram (ECG), Symmetric Finite Impulse Response (FIR), Infinite Impulse Response (IIR).

I. INTRODUCTION

Enhanced biomedical signals play a crucial role in accurately diagnosing different types of illnesses. Precise detection and classification of diseases can be achieved through improved signals. Additionally, the performance of various mediums and applications can be optimized by improving speech quality. The primary objective of the paper is to extract the signal with the highest potential signal-to-noise ratio (SNR). When recording an electrocardiogram, electrodes are attached to the patient's body to receive electrical signals. These two types of noise can negatively affect the received ECG signal and must be eliminated. To completely remove both types of interference from the ECG signal, it is necessary to design low-pass and high-pass filters. The quality of a signal is greatly affected by the choice of filter design method used.

In this case, the simple filter topology to make the design process less complex and to eliminate noises. The quality of a signal is generally correlated with the sampling frequency, with higher frequencies resulting in more accurate signal components.

This study has three main contributions:

1) Identification of crucial ECG signal components and the negative impact of noise on the signal, along with filter design methods to remove noise,

2) Examination of ECG signals from BIT/MIH database at different sampling frequencies and application of filters to compare the received signals and

3) After comparing all the signals and values of signal-to-noise ratio and mean squared value to give the result as which filter is best suited for ECG signal processing.

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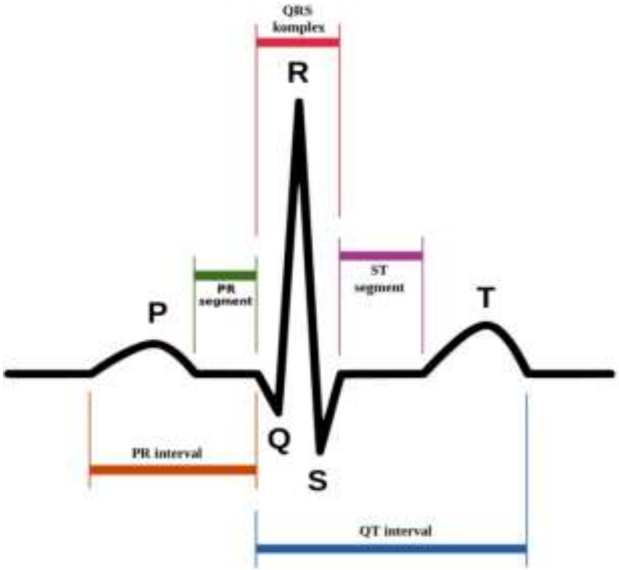


Fig 1. ECG Signal

II. DESIGNING THE MODEL

A. Digital Filters

A digital filter is a mathematical algorithm that is utilized in both hardware and software to achieve filtering objectives by taking digital input and producing digital output signals. Digital filters serve two primary purposes: splitting combined signals and restoring distorted signals that require separation due to interference, noise, or other signals. Filters may fall into several categories, including linear or non-linear, time-invariant or time-variant, causal or non-causal, analog or digital, discrete-time or continuous-time, passive or active type of continuous-time filter, and infinite or finite impulse response as a type of digital or discrete-time filter. Recursive filters (IIR filters) are a type of filter that use feedback connections to achieve the desired filter implementation. The FIR system utilizes a finite duration impulse response sequence that consists of a limited number of non-zero terms. Non-recursive structures, which only have zeros and no feedback, are typically used to implement FIR filters.

B. Design of High Pass and Low Pass Filters

To eliminate high-pass and low-pass noises from the grid for ECG signals, it is important to create high-pass and low-pass filters. The two commonly used types of filtering are FIR and IIR filters, which are described by

$$y(n) = \sum b_k * x(n-k) \text{ --------(1)}$$

$$y(n)=\sum b_k * x(n-k)+\sum a_i * y(m-i) \text{ --------(2)}$$

where n-order of the signal, x(n)-input signal, y(n)-output signal

Symmetrical FIR filters are always stable and do not distort the signal, but they require substantial computation and must be selected appropriately for their intended use. An odd number of coefficients in a symmetrical FIR filter results in an integer delay between the original signal and the filtered signal, which can be calculated using a specific formula. IIR filters have a smaller order number than FIR filters, but they can distort the signal and must be designed with stability in mind.

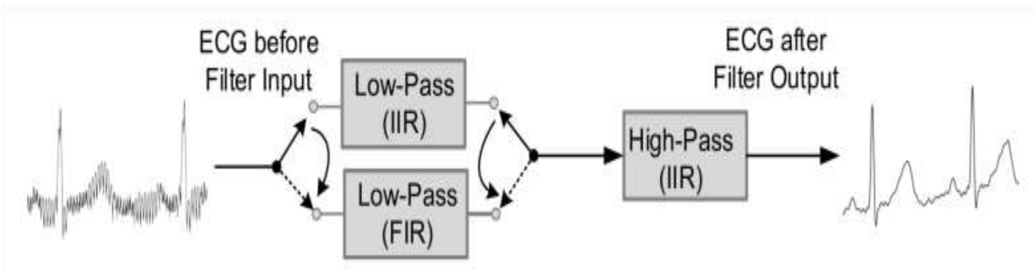


Fig 2. ECG signal when filters applied

III. IMPLEMENTATION

In order to obtain reliable results for ECG signal without noise MATLAB is used, which is a crucial tool that offers several advantages over traditional programming languages when it comes to technical problem-solving. These advantages include ease of use, platform independence, predefined functions, device-independent plotting, a graphical user interface, and the ability to easily compile code. To use MATLAB for ECG signal analysis, the signals are first loaded from a database and combined with simulated signals, followed by the addition of noise. The time domain examination of this added signal allows for the determination of appropriate design parameters for various digital filters.

The database BIT/MIH has a sampling frequency of 360 Hz which will be examined in this section along with the ECG signal extracted from it. To analyze the ECG signal with smaller sampling frequencies, a new sampling frequency of f_{new_fre} = (30, 45, 72, 90, 120, 180) Hz is chosen.

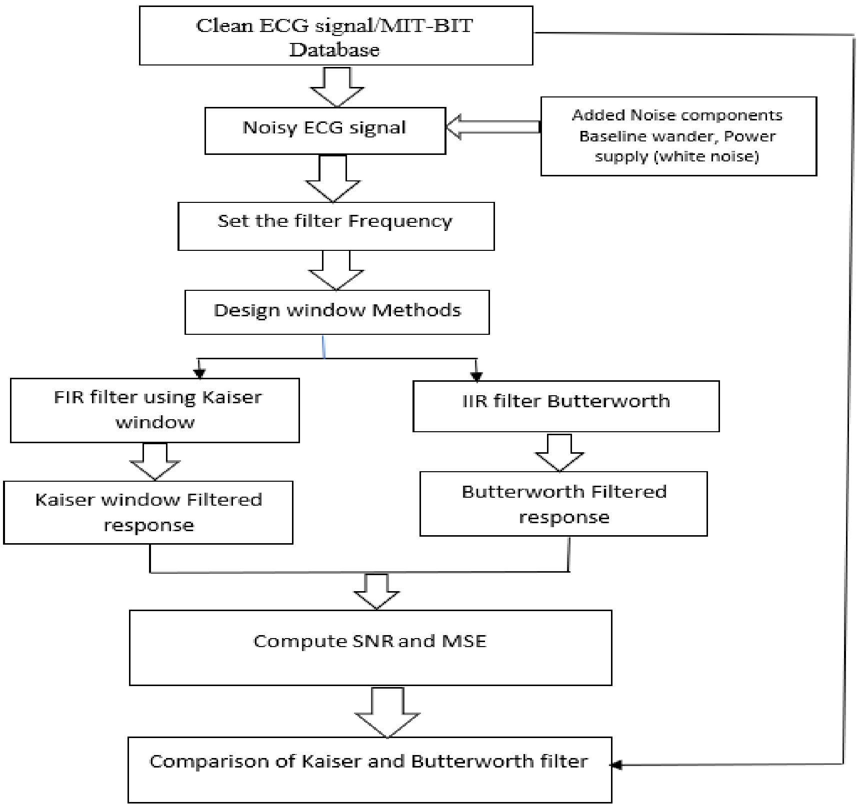


Fig 3. FIR and IIR Filters using ECG Signal with Different Sampling Frequencies

The evaluation of the new data generated from the BIT/MIH database is done by creating new databases from the MIT/BIT database with f_{new_fre} sampling frequencies, performing the filter on both new and old data, selecting the data after filtering at 360 Hz as the original data, and comparing it with the data at the new sampling frequencies. The comparison standards include signal to noise ratio and mean square. The total number of multiplication and addition calculations for the FIR/IIR filter is determined using Formulas (3) &(4).

$$FIR_{Add} = FIR_{Multi} = M \quad \text{-------------(3)}$$

$$IIR_{Add} = IIR_{Multi} = 2N - 1 \quad \text{-------------(4)}$$

Where M-order of FIR filter,N-order of IIR filter

IV. RESULTS

The output of the filtering system is accessible through the application. This displays the results of original ECG signal, noise signal and combination of these two signals. It also gives the values of signal to noise ratio(SNR) and mean square error (MSE) before and after filters applied to ECG signal. Below graphs shows the results obtained in MATLAB.

In Fig 4.It shows the ECG signal with different time and frequencies as (a) time=10s & frequency =60Hzand (b) 1 min & frequency =360Hz.The random noise is added to both ECG signal.

In Fig 5.It shows the ECG signal in time domain with different sampling rate when both Kaiser and Butterworth approximation are applied.

In Fig 6.It shows the ECG signal in frequency domain when both Kaiser (FIR) and Butterworth approximation (IIR) filters are applied.

In Fig 7.It shows that the SNR and MSE values of ECG signal having different sampling frequencies before and after filters are applied. It is observed that when different frequency signals are applied the SNR and MSE of signal changes.

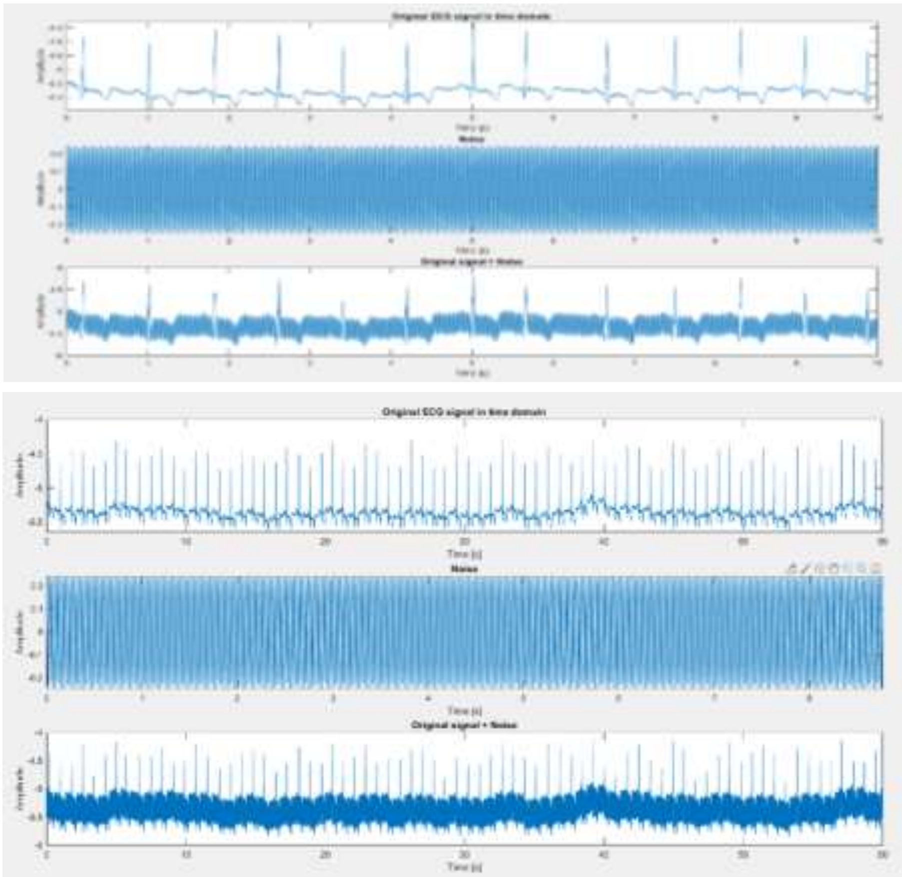
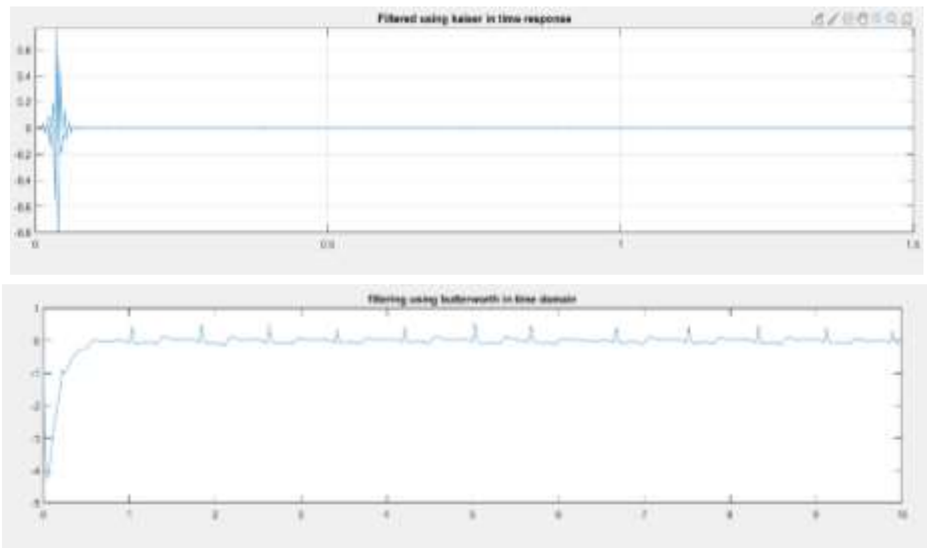


Fig 4. ECG signal (a) Original ECG from BIT/MIH (b) Random noise signal (c) Original signal + Noise



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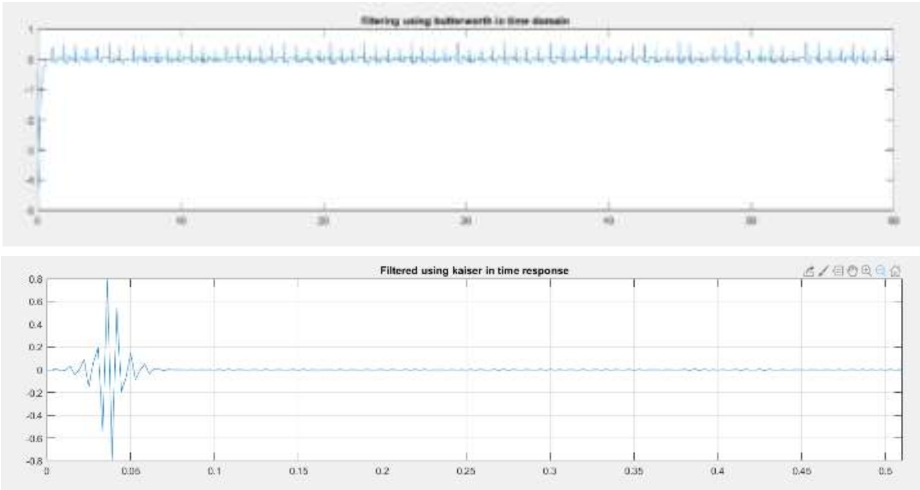

Fig 5. Filtered ECG using Kaiser and Butterworth approximation in Time domain

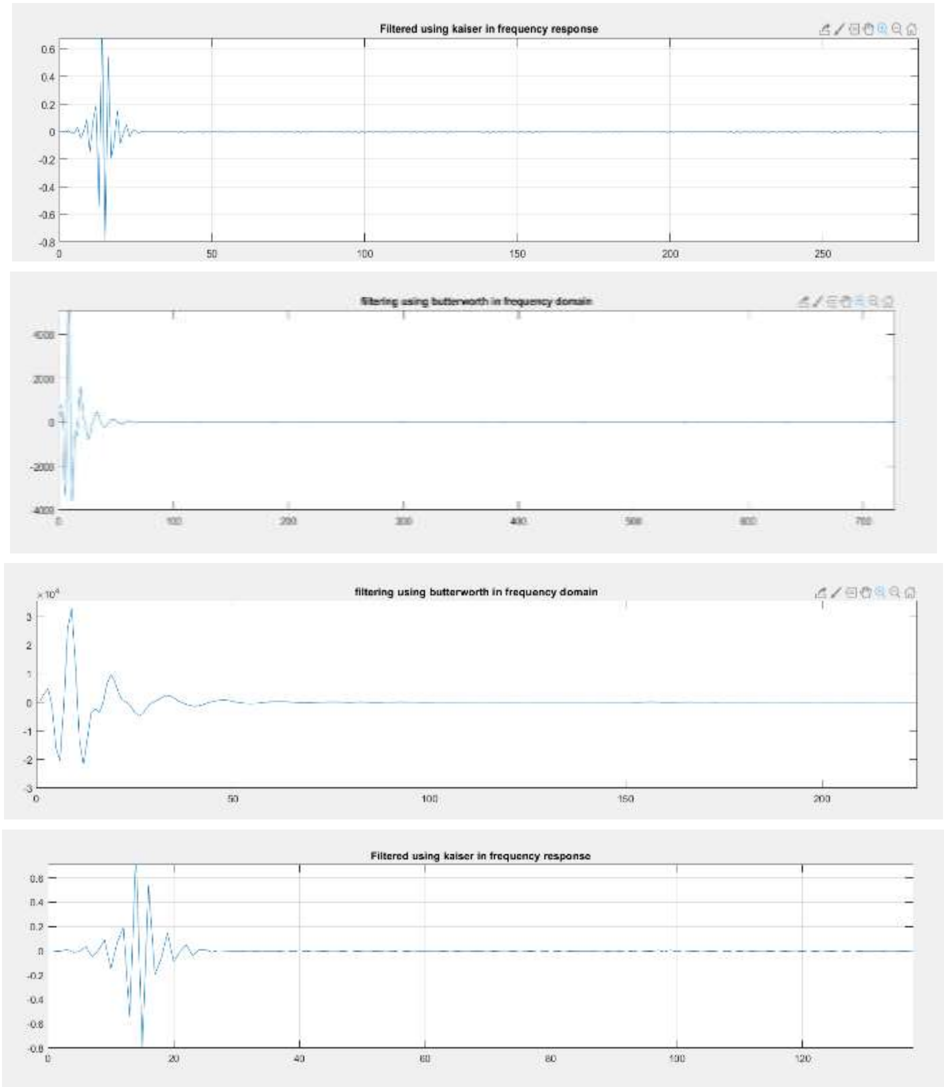

Fig 6. Filtered ECG using Kaiser and Butterworth approximation in Frequency domain

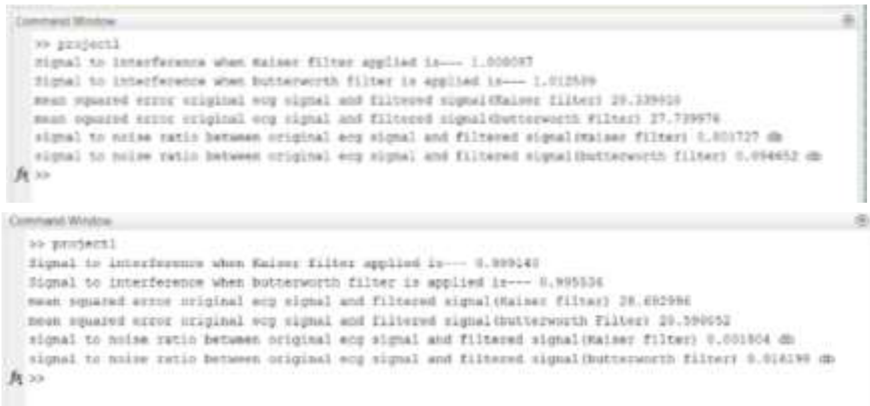

Fig 7. SNR & MSE values before and after filtering is applied to ECG signal

V. CONCLUSION

After careful examination, It is determined that the Kaiser window (FIR) filter has more flexibility in realizing ECG signal compare to Butterworth approximation (IIR) filter. However, depending on the requirements of an ECG machine, a filtering technique can be chosen accordingly. Comparison of FIR and IIR filters using ECG Signal with Different Sampling Frequencies is particularly useful in processing ECG signals, improving the signal-to-noise ratio, obtaining clear recordings, and preserving the signal's original shape. Additionally, it reduces design complexity and provides low-cost solutions for ECG signal processing.

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