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# Digital Elliptic Filter Application For Noise Reduction In ECG Signal

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*Abstract:*
Digital filters plays very important role in the processing of the low frequency signals. Numbers of biomedical signals are of the low frequency. The ECG signal, which preliminary represents the condition of the heart. It has the frequency range form .5 Hz to 100Hz. Artifacts introduced in the signal create numerous difficulties against the physician. The work is the step in the direction for reduction of the artifacts using digital filter. The paper deals with design of the well-known elliptic filter in digital domain. The three filters of the elliptic approximation are designed and implemented on the real time ECG signal. The real time ECG signal is extracted using instrumentation designed with the help of the instrumentation amplifier from INA series. It is found that the elliptic filter introduced works well as compared to the Butterworth, chebyshev type I & type II with some limitations. In general overall filter works satisfactorily.

*Key Words:* Electrocardiogram, Elliptic Digital Filter, Real Time Filtering.

## 1. Introduction

Most of the biomedical signals appears as weak signals in an environment that is teemed with many other signals of varies origins. Any signal other than that of interest is termed as interference, artifacts or simply noise. The sources of the noise could be physiological, the instrumentation used, or the environment of the experiment.. Noise is omnipresent! The problem caused by the artifacts in biomedical signals are vast in scope and variety; there potential for depredating the performance of the most sophisticated signal processing algorithm is high. The present work with the generic statement of problem and investigate its nature is 'analysis varies types of the artifacts that corrupt the biomedical signals and explore filtering technique to remove them without degrading the signal of interest. The biomedical signal in the present work is the ECG signal and the filtering technique suggested is elliptic filter or simply cauer filter. This ECG gets corrupted due to different kinds of the artifacts. The different types of artifacts are Power line interference, motion artifacts, base line drift and instrumental noise. Due to these types of the artifacts ECG gets corrupted and correct information not transfers to the cardiac specialist. The care must be taken to nullify the artifacts to avoid wrong diagnosis. Certain type of the noise may be filter directly by time domain filters using signal processing techniques or digital filters. The advantage of the time domain filtering is that the spectral characterization of the filter may not be required (at least in the direct manner). Different researchers are working on noise reduction in the ECG signal. Wu Y, Yang Y in his article given new method for the ECG noise reduction by using 50 persons ECG based on Levkov method [1]. The Wang H, Dong X has suggested filter method with in filtered QRS wave can be exactly regarded as the mark identifying other physiological Signal. [2]. The method for the removal of the power line interference suggested by ferdJallah M, Barr RE based on iterative division or multiplication of a set of frequencies centered at 60 Hz[3]. The Choy TT, Lenng PM has suggested in his literature the real time microprocessor based notch filter for ECG[4]. The Mc manus CD, Neubert KD has compared the digital filtering methods[5,6]. The technique for suppressing transient states of ECG the IIR notch filter is investigated by Pie SC and T Seng CC [7]. The work on the ECG beat detection using filter bank is carried out by the Tompkins W J and Luos [8]. Other method like Signal averaging for line interface reduction is also suggested by the scientists [9,10].

In the frequency domain filtering many design procedures are available in the literature. In the present work elliptic filter is suggested for the artifacts removal. Basic block diagram of the system used for the proposed work is shown in the figure 1

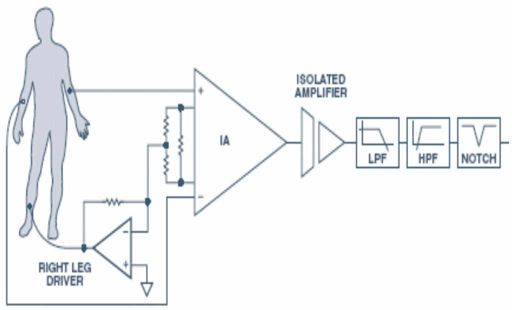


Figure 1: Basic block diagram of the system used for Filtering The ECG Signal.

In the block diagram shown with figure 1 instrumentation is built with the help of INA series instrumentation amplifier. The instrumentation amplifier provides amplified version of the ECG signal. For protection purpose the isolation amplifier has been used. Instrumentation amplifier and Isolation amplifier forms the analog domain. The LPF, HPF, NOTCH shown in the figure 2are the elliptic filter, which are designed digitally so they forms the digital domain. The analog part provides the unfiltered ECG signal. The efforts have been made to reduce the noise present in the ECG signal.

**2.Design of the Elliptic filter**

These filters exhibit equiripple behavior in the pass band as well as in the stop band. They are similar in magnitude response characteristic to FIR equiripple filter. Therefore elliptic filters are optimal filters in that they achieve the minimum order n for given specification (or alternatively, achieve the sharpest transition band for the given order N). These filters for obvious reasons, are very difficult to analyze and therefore, to design. It is not possible to design them using simple tools, and often programs or tables are needed to design them.

The magnitude-squared response of elliptic filter is given by

$$\left|H_a(j\Omega)\right|^2 = \frac{1}{1+\in^2 U_N{}^2\left(\frac{\Omega}{\Omega_c}\right)} \quad \ldots\ldots\ldots\ldots(1)$$

Where N is the order, $\in$ is the pass band ripple (which is related to $R_P$ ), and $U_N(.)$ is the $N^{th}$ order Jacobian elliptic function . Even though the analysis of equation (1) is difficult, the order calculation formula is very compact.[10,11,12]. It is given by

$$N = \left(\frac{K(k)K(\sqrt{1-k_1{}^2})}{K(k_1)K(\sqrt{1-k^2}}\right) \ldots\ldots\ldots(2)$$

$$\text{Where, } k = \frac{\Omega_P}{\Omega_S},$$

$$k_1 = \frac{\in}{\sqrt{A^2 - 1}} \text{......(3)}$$

$$K(x) = \int_0^{\pi} \frac{d\theta}{\sqrt{1 - x^2 \sin\theta}} \text{.........(4)}$$

is the complete integral of the first kind. MATLAB provides the function *ellipke* to numerically compute the above integral. MATLAB provides a function called [z,p,k]=*ellipap*(N,$R_P$,$A_S$) to design a normalized elliptic analog prototype filter of the order N , Passband ripple $R_P$ , Stopband attenuation $A_S$ , it gives pole and zeros and constant K after designing analog prototype filter it is required to convert it into digital filter using any method. In the present work, the required ECG signal containing important information lies only in the frequency range of .5Hz to 100Hz. Therefore to study the application of elliptic filter on ECG three filters are designed viz low pass, High pass, Band stop of 50 Hz for removal of power line interference. All designs are performed using filter design toolbox in the MATLAB. The sampling frequency for the design is 1000 Hz. The low pass filter is design for the 100Hz cutoff frequency and order 4. Figure 2,3,4,5 shows the Magnitude response, Phase response, pole zero response and the realization of the filter respectively. The high pass filter is designed for the frequency of .5Hz. Figure 6,7 Shows the Magnitude response, Phase response, pole zero response and the realization of the high pass filter respectively. Similarly Notch filter of 50 Hz has been designed for removal power line interference for the order of 4. Figure 8,9,10,11 Show the Magnitude response, Phase response, pole zero response and the realization of the notch filter respectively. It is seen that elliptic filter provides optimal performance in the magnitude squared response but have highly nonlinear response in the pass band which is highly undesirable in many applications. In comparison with the butterworth filter it has maximally flat magnitude response and higher order N (more poles) to achieve same stopband specifications and they exhibits a fairly linear phase response in their pass band. The Chebyshev filters have phase characteristics that lie somewhere in between.

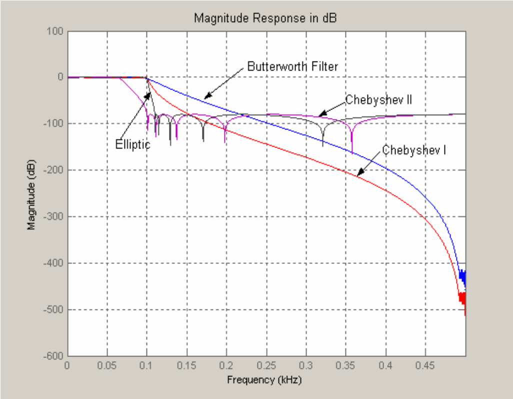


Figure2: magnitude Response of the elliptic low pass filter

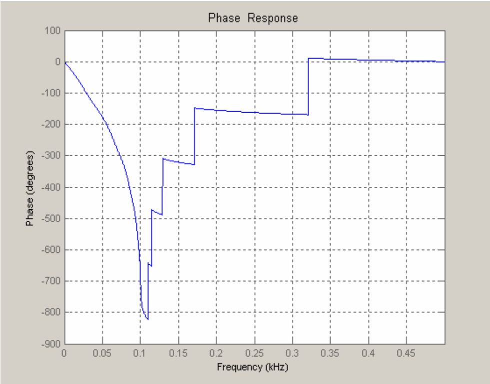


Figure3: Phase Response of the elliptic low pass filter

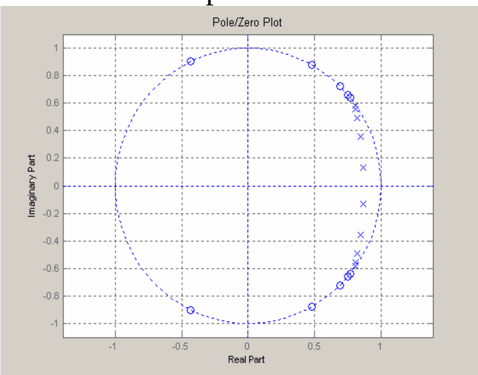

Figure4: Pole Zero pattern of the elliptic low pass filter

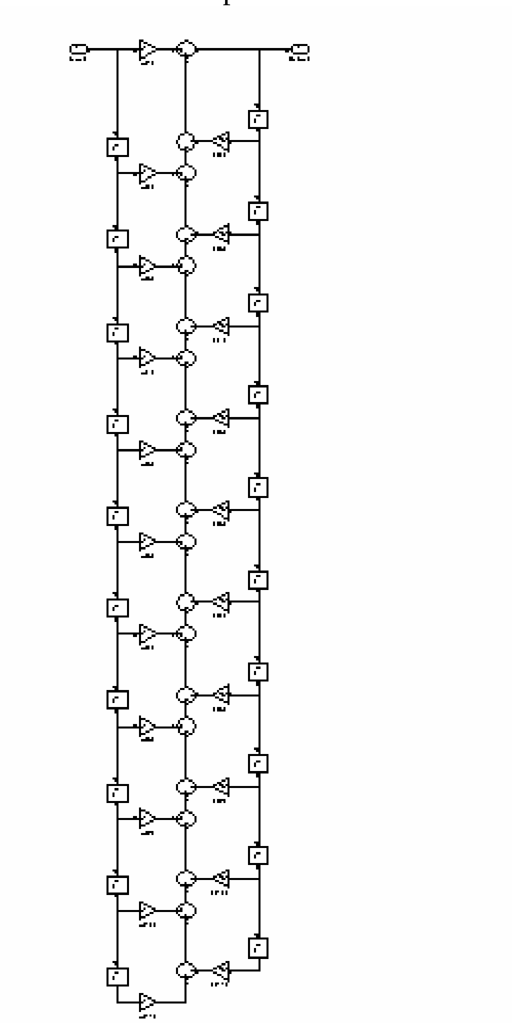

Figure5 realization of the Low pass elliptic filter

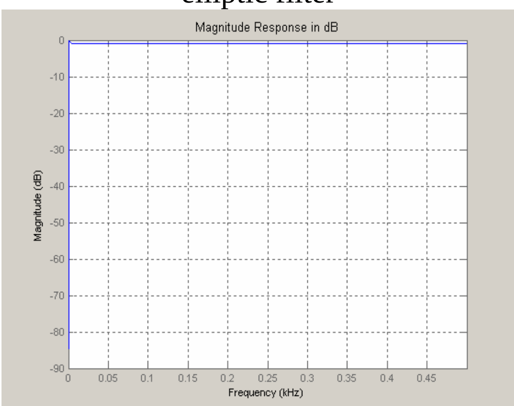


Figure6: magnitude Response of the elliptic High pass filter

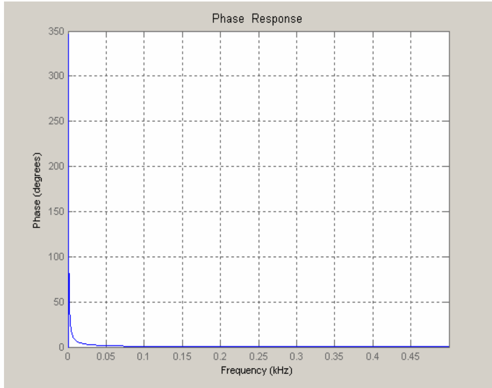


Figure7: Phase Response of the elliptic low pass filter

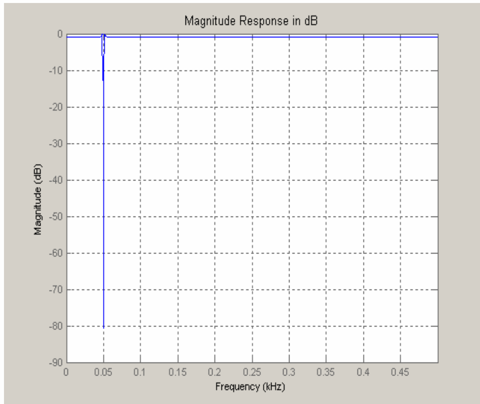


Figure8: magnitude Response of the elliptic Notch filter

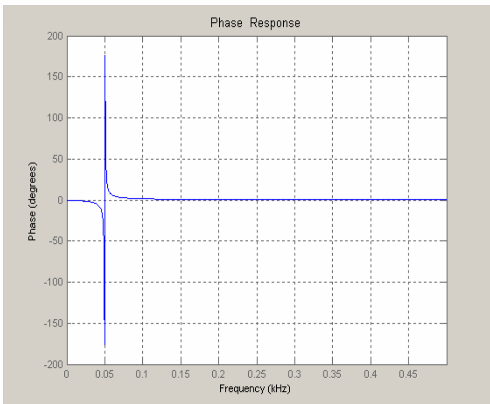


Figure9: phase Response of the elliptic notch filter

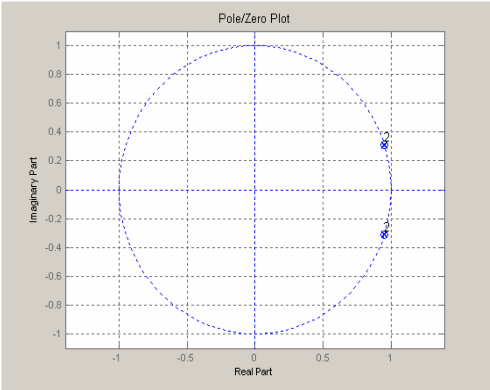


Figure10: pole zero pattern of the of the elliptic notch filter

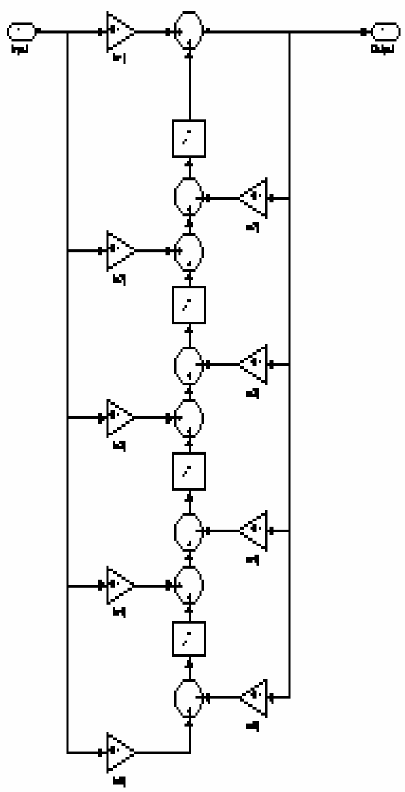

Figure11: Realization of the elliptic notch filter

### 3. Application of Filter to ECG

The model using three elliptic digital filters is built in the Matlab. All the three filters are cascaded. The output of the Filter cascade combination is given to the time scope. The model is built in the simulink of the MATLAB. In the model, digital inputs indicates the ECG, out of the ADC. For accessing ECG signal 711B adds on card has been used. This application also requires the real time window of the MATLAB.

### 4. Results And Conclusions:

Figure. Shows nature of the ECG waveform for the Lead aVR combination when the three filters are cascaded. Figure 12,13 Shows the notch filter implementation to the corrupted ECG signal. The power spectrum of the signal before filtration and after filtration Visual inspection shows that the most of the noise present in the signal after amplification is eliminated using elliptic filter.

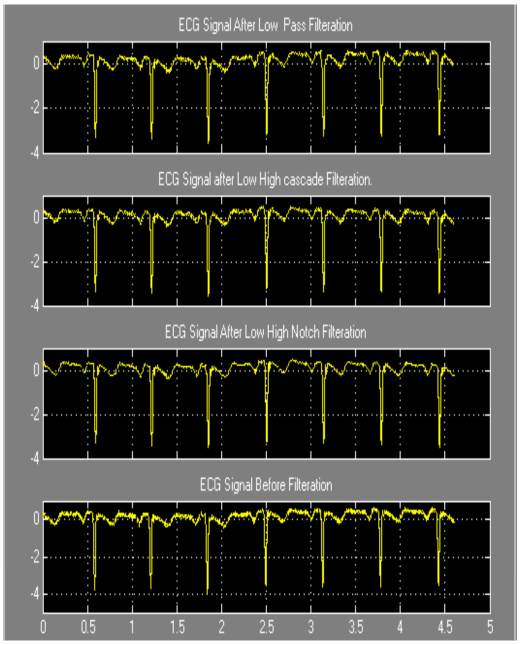


Figure12: Filtration result for the aVR lead combination.

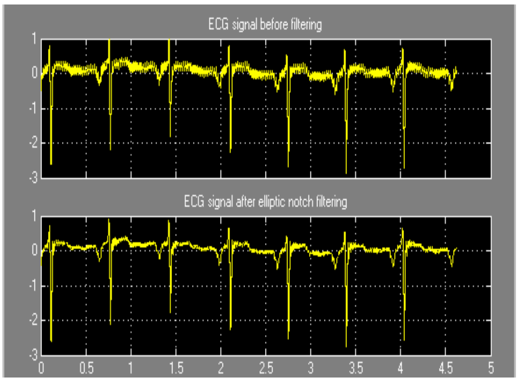

Figure13: Results of Notch elliptic filter of 50 Hz.

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