Design of ECG Instrumentation and implementation of Digital filter for Noise reduction

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Abstract:
The biomedical topic that attracted the early interest of engineers is that of electrocardiography. It is the most useful noninvasive medical diagnostic tests and is in very wide use (an estimated 200 million ECG s taken each year). Its technological challenge is to improve performance by increasing the number of simultaneously recorded signal, raising the signal to noise ratio. The increase in data acquisition rate also provides new challenges in the design of recording systems including the application of methods of data compression. The electrocardiogram has the considerable diagnostic significance, and applications of ECG monitoring are diverse and in wide use. Different types of noise due do which ECG gets corrupted. The various noise types considered were 50Hz power line interference, base line drift due to respiration, abrupt base line shifts, and a composite noise constructed from all of the other noise types. Different digital filter structures are presented in the paper to eliminate these diverse forms of noise sources and their performance is discussed with reference to efficiency, distortion of the signal. The ECG signals used in this study were obtained by designing twelve lead instrumentation amplifier. The design system leads to prototype device for the ECG. To remove low frequency and Power line interference in the ECG signal, digital filter based on least mean squares has been implemented and presented in the paper.

Keywords: ECG, Least squares method, ECG Instrumentation, Real time filtering.

1. Introduction:

The registration of the ECG signal Known as electrocardiogram, Represents the recording of the electrical potential of the heart. Physicians record ECG signal easily and noninvasively by attaching small electrodes to the human body. Electrocardiogram is the standard tool to diagnose the heart disease. While diagnosis the different artifacts get introduced in the ECG signal like Electrode contact noise, motion artifacts, base line drift electrosurgical noise, and power line interference. Removal of this noise signal is important. Processing of the biomedical signal basically deals with filtering of the signal. Researchers are working on noise reduction in the ECG signal. Mitov shows a method for reduction of power line interference (PLI) in electrocardiograms with sampling rate integer multiple of the nominal power line frequency is developed and tested using simulated signals and records from the databases[1]. Cramer E, McManus CD, Neubert D has suggested two different filters. One is based on a least-squares error fit, the other uses a special summation method. Both methods are compared with a local predictive filter by applying each filter to artificial signals and to real ECGs [2]. Ferdjallah M, Barr RE. has given Frequency-domain digital filtering techniques for the removal of powerline noise. [3]. A method for line interference reduction to be used in signal-averaged electrocardiography systems, performance is analyzed by Ider YZ, Saki MC, Gcer HA [4]. Batchvarov V, Hnatkova K, Malik M. has done assessment study on the Electrocardiogram[5Christov II, Daskalov IK have worked on filtering of the electromyogram from the electrocardiogram[5]. von Wagner G, Kunzmann U, Schochlin J, Bolz A have described Simulation methods for the online extraction of ECG parameters under Matlab/Simulink [6]. Several othe filter desogn techniques can be found in literature [7, 8].

2. ECG Instrumentation:

The main requirement of the system was 12 lead ECG signal acquisition systems. Therefore, system has been designed considering standard parameters and strictly avoiding filter sophistication that would otherwise unnecessarily filter out the signal before allowing developed digital filters to react and process the signal to get noise less ECG. The system is designed around the components available in indigenous market and also preferring those which are commonly used in the ECG processing. The same procedure has been implemented to realize lead selection and other parts of system. The following technical specifications were decided and finalized and implemented for the system.

1. Input impedance 20 MΩ.
2. Frequency response 0.01 to 100 Hz.
3. Gain 1000.
4. Number of leads 12.
   Bipolar leads: I, II, III.
   Unipolar leads: aV_R aV_F aV_L
   Unipolar Chest leads: V_1, V_2, V_3, V_4, V_5, and V_6
5. Power Supply ± 15 V.

Basically system has been divided into four blocks

1. Input Buffer.
2. Lead Selection Network
3. Instrumentation Amplifier
4. Amplifier and filter

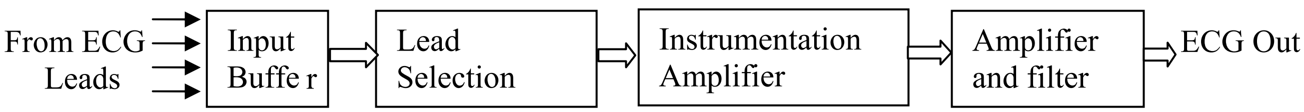

Figure 1: Block Diagram of the 12 Lead ECG Systems.

Figure1 shows basic building block diagram of the 12 lead ECG amplifier circuit. Input stage is the input buffer amplifier stage. Buffer amplifier is a section that provides very high input impedance 20Hz. In this case low output impedance which is desired for lead selection network is realized using standard operational amplifier. The output of this stage given to the seven terminal Wilson's bridge formed using typical values of resistors. A multi pole multi position selector switch is employed for desired lead selection. Next block is instrumentation amplifier. Instrumentation amplifier has been designed around dual op-amps this has the gain of 22. IC used for building an instrumentation amplifier has CMRR of 120dB. Further to this section, there are added an amplifier and filter stages. This section uses four operational amplifiers. The filter component eliminates unwanted low & high frequency components and also provides necessary gain to achieve final system gain of 1000. Figure 2 shows Wilson's bridge used for getting correct lead combination.

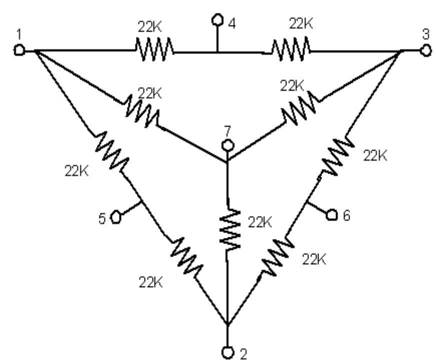

Figure 2 : Wilson's Bridge.

3. Digital filter Design and Implementation:

The model using two digital filters is built in the Matlab. The model is built in the simulink of the MATLAB. In the model, digital inputs indicate the ECG, out of the ADC. For accessing ECG signal 711B adds on card has been used. Figure 4 shows the model used in the system.

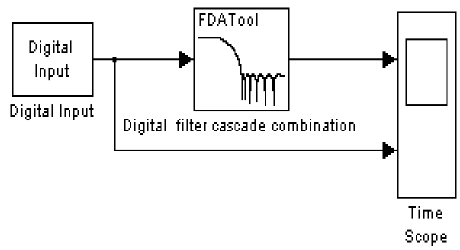

Figure 3 Simulation model used for the ECG processing.

4 Results of the implementation of the High pass filter:

Figure 4 shows the ECG signal with variation on the base line. The corresponding frequency spectrum is shown in figure 6. Figure 8 also shows the sample of the ECG signal with base line variation. Corresponding frequency spectrum is shown in figure 9. When the signal shown in the figure 4 is filtered with help of designed filter the resulting ECG trace is shown in the figure 5 and the corresponding frequency spectrum is shown in the figure 7. It is seen that only from -5dB to -7dB drop in the power corresponds to the frequency of 0.5Hz. As seen from the figure 8 and 10 that no base line variation is removed from the ECG trace. It clears that this high pass filter using least squares method is of not use.

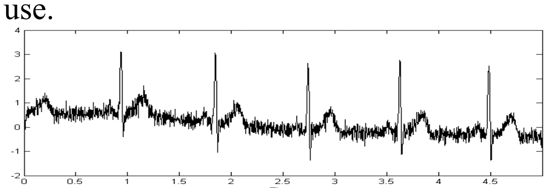

Figure 4: ECG signal before high pass filtration

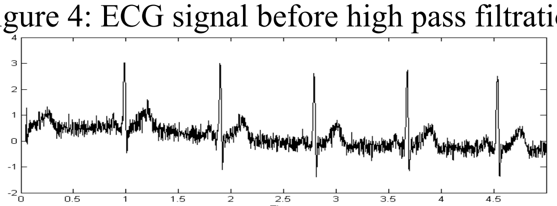

Figure 5: ECG signal after high pass filtration

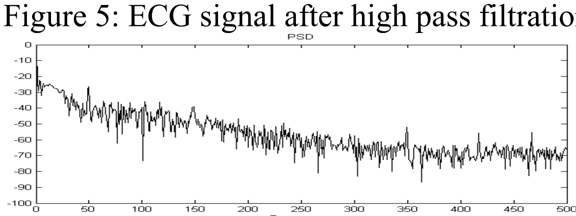

Figure 6: Frequency spectrum corresponding to figure 4

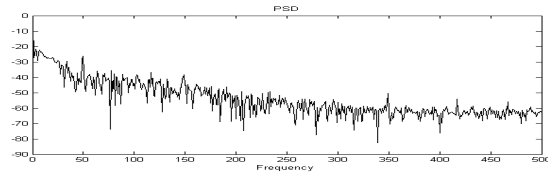

Figure 7: Frequency spectrum corresponding to figure 2

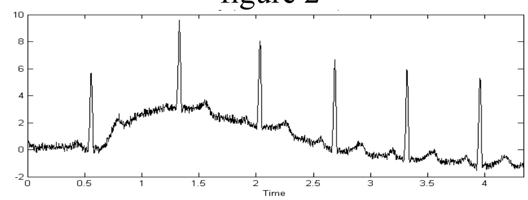

Figure 8: ECG signal tithe base line wonder before application to Filter

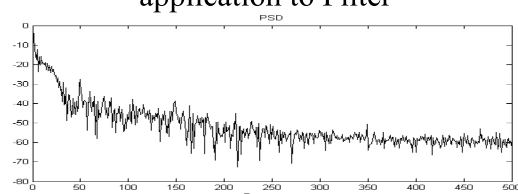

Figure 9: Frequency spectrum corresponding to figure above

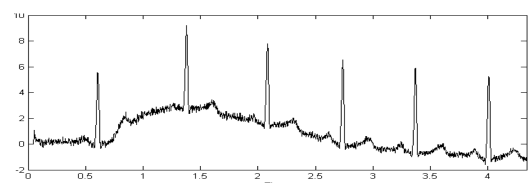

Figure 10: ECG signal after application to the filter

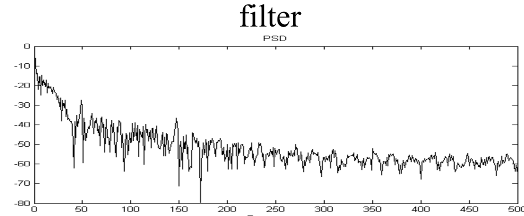

Figure 11: Frequency spectrum corresponding to figure above 10

5. Results of the implementation of the notch filter using Least squares Method:

Figure 12 and figure 13 shows the ECG signal before and after application of the notch filter designed using least squares method. Frequency responses corresponding to the ECG signal before and after filtration are shown in figure 14 and figure 15 respectively. It is clear from the figure 13 that the response time of the filter is more. No any variations in the QRS complex of the ECG signal is observed. From the figure 13 it is seen that the power of the signal corresponds to the ECG signal before filter application that is including power line interference 50 Hz is -36dB. When this signal is passed through notch filter of 50 Hz it is seen that the power corresponds to the 50 Hz is reduced to -42dB as shown in figure 15. This clearly indicates that the filter works satisfactorily for the power line interference.

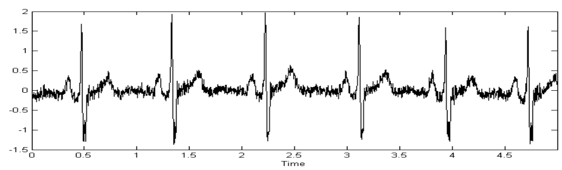

Figure 12: ECG signal before notch filter application

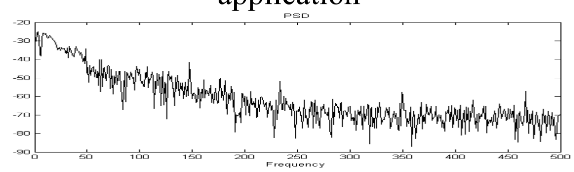

Figure 13: Frequency response corresponding to the ECG as in figure 27

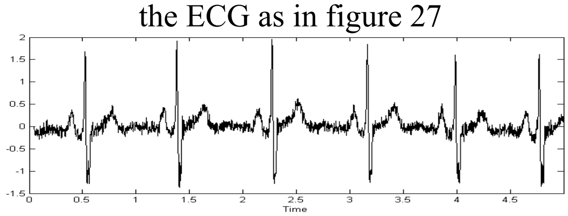

Figure 14: ECG signal after notch filter application

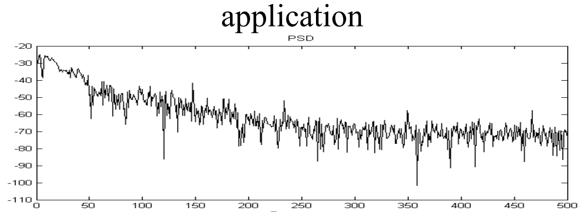

Figure 15: Frequency response corresponding to the ECG as in figure 14

6. Conclusions:

While designing the high pass filter using least squares method, order of the filter used was 100 and the sampling frequency was 1000Hz. This design gives linear phase and some ripples in the magnitude response. Filter designed with these specifications was stable. It was seen that the drop in the power was from -5dB to -7dB corresponds to the frequency of 0.5Hz. It clears that this high pass filter using least squares method is of not useful in the present application. Similar Conclusion can be drawn for using notch filter design with this method is not so useful for removal of powerline interference as compare to the other known standerd methods. By considering the results of the digital filter it is seen that high pass and notch filter applied on the ECG signal designed with least squares method is not effetcive as compared as the other methods.

7. References:

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