

Application of the Chebyshev Type II Digital Filter For Noise Reduction In ECG Signal

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Abstract:

Digital filters have a variety of applications in the Biomedical areas. The versatility of these filters allows them to be used in numerous ways, such as removing specific powerline frequencies allowing only a desirable frequency range to pass, such as isolating a QRS complex in an ECG signal, or to simply eliminating aliasing artifacts. In medicine, signals will often have a great deal of extraneous frequencies, and the use of digital filters allows the investigator to hone in on a specific, desired signal. The different noise interferences are present in the Unfiltered ECG signal. In the Paper instead of using filter using hardware for the noise removal the digital filter has been suggested. Present paper deals with the application of the chebyshev type II for the reduction of the artifacts in the ECG Signal. Design procedure, its implementation to the real time ECG and the performance is depicted in the paper. Filter works satisfactorily.

Key Words: Electrocardiogram, Chebyshev II IIR Digital filter, Real time Application.

1. Introduction:

Computer Technology has an important role in structuring biological signals. The explosive growth of high-performance computing techniques in recent years with regards to the development of good and accurate models of biological systems. The electrocardiography deals with the electrical activity of the heart the state of the cardiac health is generally reflected in the shape of the ECG waveform and heart rate.[1]. In many practical medical applications, filters are needed to obtain more relevant data from a signal, such as an ECG. Other problems, such as artifacts and powerline frequencies often add unwanted data to these signals. Analog filters help deal with these problems. However, they may introduce non-linear phase shifts, skewing the signal. Also, the instrumentation depends on resistance, temperature, and design, which may also

introduce more error. With more recent technology, digital filters are now capable of being implemented. Digital filters are much more precise due to a lack of instrumentation, thus offering a great advantage over analog filters. Digital filters can be placed into one of two categories: Finite Impulse Response (FIR), and Infinite Impulse Response (IIR). All digital filters extend over a frequency range of $-\omega_s/2$ to $\omega_s/2$, where ω_s is the angular sampling frequency. The electrical activity of the heart is integral to the operation of several types of medical instruments, including the electrocardiograph, the pacemaker, and the defibrillator. A very small electrical disturbance can cause this vital organ to cease pumping blood necessary to sustain life. The heart consists of two major smooth muscles the atrium, and the ventricle which form the syncytium, or fusion of cells, that conducts depolarization from one cell to the next. Because of the ionic leakage in the

smooth muscle membrane the tissue of the heart depolarizes spontaneously from its resting state and effectively oscillates, or beats.

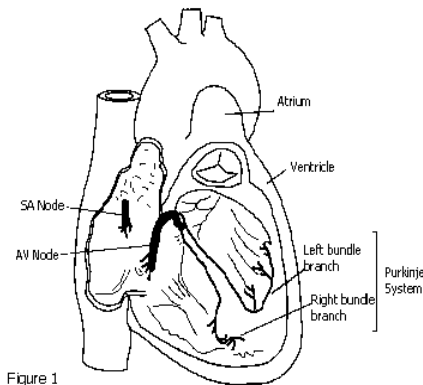


Figure 1

Figure 1: Activity of the Heart

The sinoatrial (SA) node beats at a rate of from 70 to 80 beats per minute (bpm) at rest. The atrioventricular (AV) node beats at 40 to 60 bpm and the bundle branch oscillate at 15 to 40 bpm. The SA node, Figure 1, normally determines the heart rate, since it beats at the fastest rate and causes stimulation of the other tissues before it reaches its self-pacing threshold. Thus, the SA node can be considered the heart's pacemaker. The depolarization of the SA node spreads through out the atrium and reaches the AV node in about 40ms. Because of the low conduction velocity of the AV node tissue, it requires about 110ms for the depolarization to reach the bundle branches called the Purkinje system. The ventricles then contract, the right ventricle then forcing blood into the lungs, the left ventricle pushing blood into the aorta and subsequently through the circulation system. The contraction period of the heart is called systole. The action potentials in the ventricle hold for 200 – 250ms. This relatively long time allows the ventricular contraction to empty blood into the arteries. The heart then re-polarizes during the rest period, called diastole, and then the cycle repeats.

1.1 Electrocardiogram

During diastole, while the heart is at rest, all of the cells are polarized so that the potential inside each cell is negative with respect to the outside. Normally,

depolarization occurs first at the SA node, making the outside of the tissue negative with respect to the inside of the cells and making it negative with respect to the tissues not yet depolarized. This imbalance results in an ionic current, causing the left arm to measure positive with respect to the right arm. The resulting voltage is called the P wave.

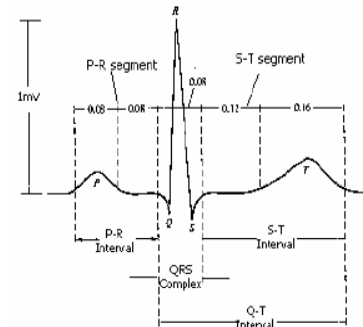


Figure 2 Basic Electrocardiogram

After about 90 ms, the atrium is completely depolarized, and the ionic current measured by lead I reduces to zero. The depolarization then passes through the AV node causing a delay of 110ms. The depolarization then passes to the right ventricular muscle depolarizing it and making it negative relative to the still polarized left ventricular muscle. Again the direction of I causes a + to - voltage from LA to RA called the R-wave. The complete wave form is called an electrocardiogram with labels P, Q, R, S, and T indicating its distinctive features. The P wave arises from the depolarization of the atrium. The QRS complex arises from depolarization of the ventricles. The magnitude of the R-wave within this complex is approximately 1mV. The T wave arises from re-polarization of the ventricle muscle. The U wave that some times follows the T-wave is second order effect of uncertain origin and is of little diagnostic significance. The intervals, segments, and complexes are shown in the Figure 2. In recent years the trend towards automated analysis of electrocardiograms has gained momentum. Many systems have been implemented in order to perform such tasks as 12- lead offline electrocardiogram analysis, Holter tape analysis in real-time

patient monitoring. This requires accurate detection of various parameters of interest even in the presence of noise. For accurate detection however steps have to be taken to filter out or discard the noise. Filtering can alter the signal and may require substantial computational overhead. The different researchers have worked on the noise present in the ECG and developed the methods to eliminate it.[2-4]. In the ECG processing the detection of the QRS complex is very important many peoples have worked on it and compared the different QRS detection algorithms [5-11]. The Kaiser W, Findeis M. has worked on the processing of the artifacts during the stress.[12]. In the proposed work different artifacts has been studied and efforts have been made for reduction of it. To do this efforts are made to design and implement three digital filters, and to apply it to the ECG Signal. The ECG signals used in this study are real time and all the work is done in MATLAB. However a separate data acquisition module was also designed which is capable of picking the analog ECG signals.

1.2 Noise Artifacts

Electrocardiographic signals (ECG) may be corrupted by various kinds of noise. Typical examples are:

1. Power line interference
2. Electrode contact noise.
3. Motion artifacts.
4. Muscle contraction.
5. Base line drift.
6. Instrumentation noise generated by electronic devices.
7. Electrosurgical noise.

1.2.1 Power line interference

It consists of 50-60Hz pickup and harmonics, which can be modeled as sinusoids. Characteristics, which might need to be varied in a model of power line noise, of 50Hz component include the amplitude and frequency content of the signal. The amplitude varies up to 50 percent of the peak to peak ECG amplitude. Where power signal is affecting the signal between 1000 to 3000 units of time.2

1.2.2 Electrode contact noise

It is a transient interference caused by loss of contact between the electrode and the skin that effectively disconnects the measurement system from the subject. The loss of contact can be permanent, or can be intermittent as would be the case when a loose electrode is brought in and out of contact with the skin as a result of movements and vibration. This switching action at the measurement system input can result in large artifacts since the ECG signal is usually capacitively coupled to the system. It can be modeled as randomly occurring rapid base line transition, which decays exponentially to the base line value and has a superimposed 60Hz component. Typically the values of amplitude may vary to the maximum recorder output.

1.2.3 Motion Artifacts

Motion artifacts are transient base line changes caused by changes in the electrode-skin impedance with electrode motion. As this impedance changes, the ECG amplifier sees a different source impedance which forms a voltage divider with the amplifier input impedance therefore the amplifier input voltage depends upon the source impedance which changes as the electrode position changes. The usual cause of motion artifacts will be assumed to be vibrations or movements of the subjects. The peak amplitude and duration of the artifact are variable. This type of interference represents an abrupt shift in base line due to movement of the patient while the ECG is being recorded. It is simulated by adding a dc bias for a given segment of ECG.

1.2.4 Muscle contraction

Muscle contractions cause artifactual mill volt level potentials to be generated. The baseline electromyogram is usually in the microvolt range and therefore is usually insignificant. It is simulated by adding random noise to the ECG signal. The maximum noise level is formed by adding random single precision numbers of 0.50% of the ECG maximum amplitude to the uncorrupted ECG.

1.2.5 Base Line Drift with Respiration

The drift of the base line with respiration can be represented by a sinusoidal component at the frequency of respiration added to the ECG signal. The amplitude and the frequency of the sinusoidal component should be variables. The variations could be reproduced by amplitude modulation of the ECG by the sinusoidal component added to the base line.

1.2.6 Noise generated by electronic devices

The parameter detection algorithms cannot correct artifacts generated by electronic devices. The input amplifier saturates and no information about the ECG reaches the detector. In this case manual preventive and corrective action needs to be undertaken.

1.2.7 Electrosurgical noise

It completely destroys the ECG and can be represented by a large amplitude sinusoid with frequencies approximately between 100 kHz to 1MHz.

2 Design of the Chebyshev II Filter

Chebyshev filters are of two types: Chebyshev I filters are all pole filters which are equiripple in the pass band and are monotonic in the stop band. Chebyshev filters contain both poles and zeros exhibiting a monotonic behavior in the pass band and equi-ripple in the stop band. The frequency response of the filter is given by

$$|H(\Omega)|^2 = (1 + \epsilon^2 T_N^2(\Omega/\Omega_p))^{-1}$$

Where ϵ is a parameter related to the ripple present in the pass band

$$T_N = \cos(N \cos^{-1} x) \quad |x| \leq 1$$

$$= \cosh(N \cosh^{-1} x) \quad |x| \geq 1$$

Considering the advantages of the digital filter Chebyshev type II Filter has been designed and implemented. To get more effect the Low pass, High pass and notch The low pass filter designed is of the order 10 and cutoff frequency 100 Hz, high pass filter is of the order 4 and cutoff frequency .05Hz. and notch filter of the order 4 and cutoff frequency of 50 Hz. filters are designed. Responses of each of

the filter are shown in the figure 3,4,5 below.

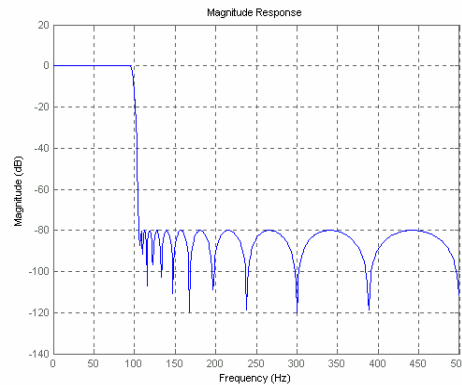


Figure 3a: magnitude Response of the Chebyshev II Low Pass Filter with order 10 cutoff frequency 100 Hz

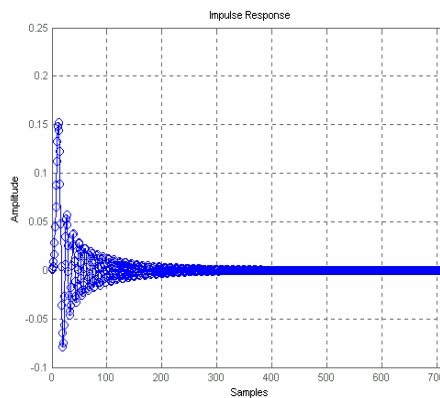


Figure 3b: Impulse Response of the Chebyshev II Low Pass Filter with order 10 cutoff frequency 100 Hz

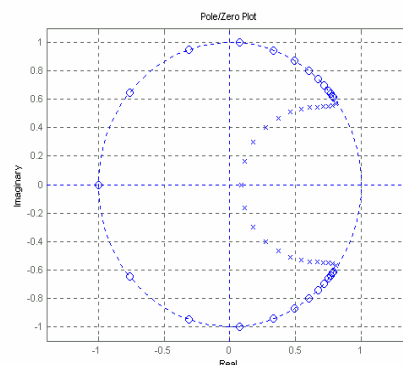


Figure 3c: Pole Zero Diagram of the Chebyshev II Low Pass Filter with order 10 cutoff frequency 100 Hz

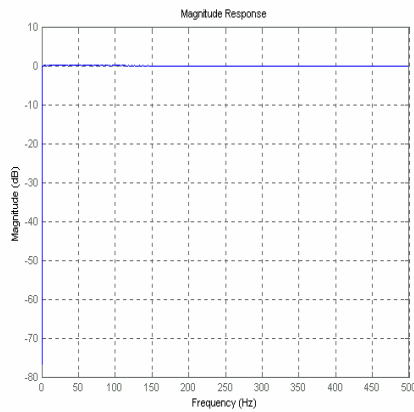


Figure 4.a: Chebyshev II high pass filter, order=4, fs=1000, fstop=0.05.

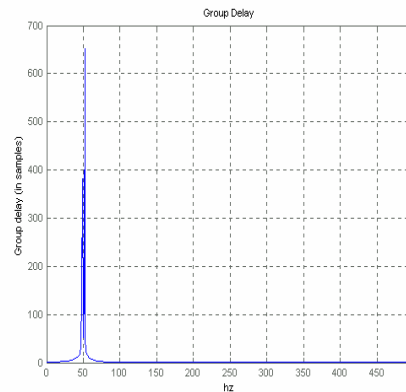


Figure 5.a: Group Delay for Chebyshev II notch filter, order=4, fs=50Hz

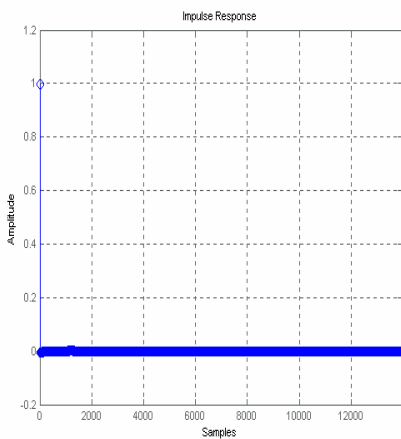


Figure 4.b: Impulse Response of Chebyshev type II high pass filter, order=4, fs=1000, fstop=0.05.

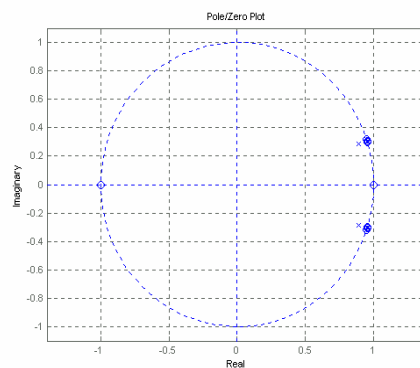


Figure 5.b: Pole Zero diagram for Chebyshev II notch filter, order=4, fs=50Hz.

The following observations are made from the frequency response of the Chebyshev II filter:

1. The designed filter meets the specifications.
2. The pass band is the flat. Value less than zero, indicating lagging phase.
3. The stop band is characterized by the presence of ripples, each having the same amplitude.
4. The phase response is approximately linear for lower pass band frequencies.

From the impulse responses which decays with time, It can infer that the designed filters are stable. This is affirmed by the pole-zero diagrams, in which all the poles reside within the unit circle. The pole zero diagrams also contain zeros which reside on the unit circle.

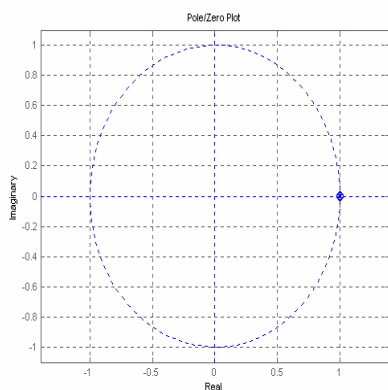


Figure 4.b: Pole zero diagram of Chebyshev type II high pass filter, order=4, fs=1000, fstop=0.05.

3 Model used in the proposed work:

Using matlab the model is built in the simulink and implemented on the ECG signal. In the model the Designed Low pass, high pass and notch filter has been cascaded figure shows the basic model used. In the model the real time input is the ECG Signal. The ECG signal is taken from the 12 lead ECG amplifiers which was designed in the laboratory. The output of the amplifier is connected to the addon Card manufactured by ADVANTECH 771B. The proper addresses are selected so

that the card is accessed in the MathLab. ECG amplifier gives the unfiltered output which contains the noise artifacts. The Power spectrum in the Figure Shows In the unfiltered signal the power line interferences as well as the high frequency noise is present This nose is to be eliminated so that no information in the ECG signal missing Figure 6.a shows the model used for the filtration of the ECG signal. Figure 6.b shows the Basic block diagram for the system used for the filtration of the ECG signal.

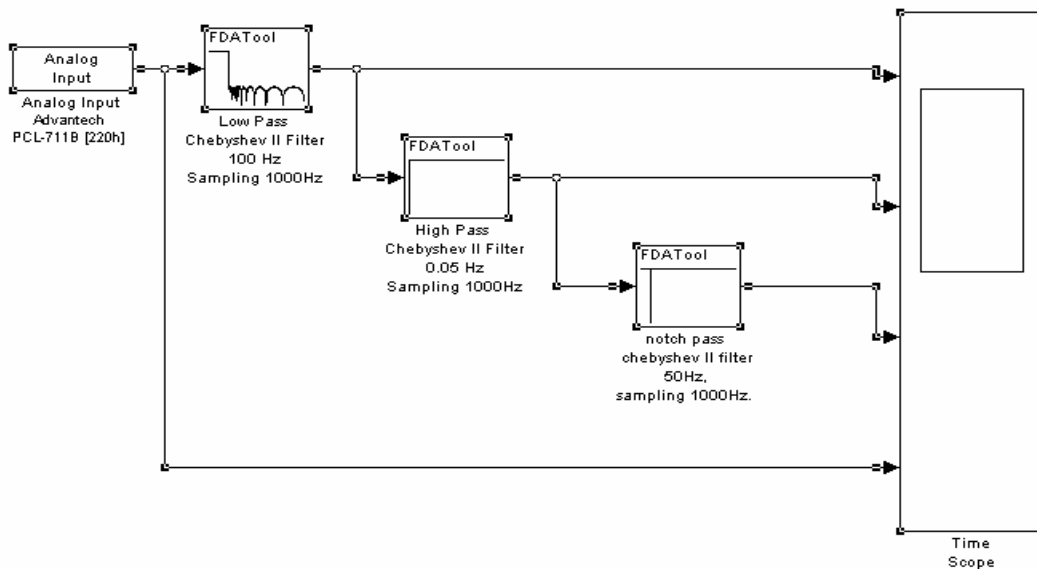


Figure 6 a. Model of the filter used in ECG filtering.

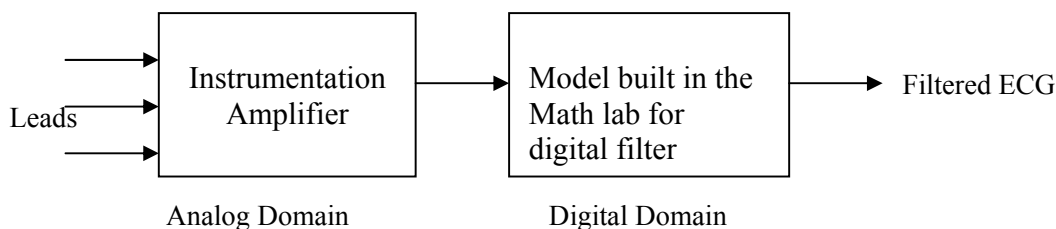


Figure 6.b Block Diagram for system used for the noise reduction in the ECG

4 Results:

This section presents the different lead combinations clearly showing the Noise reduction due to different filters. The filters work satisfactorily.

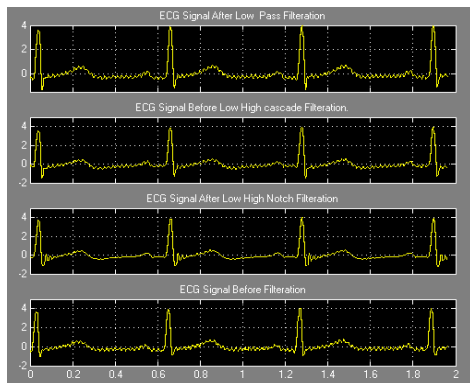


Figure 7.a ECG lead I signal of Chebyshev-II cascade filter.

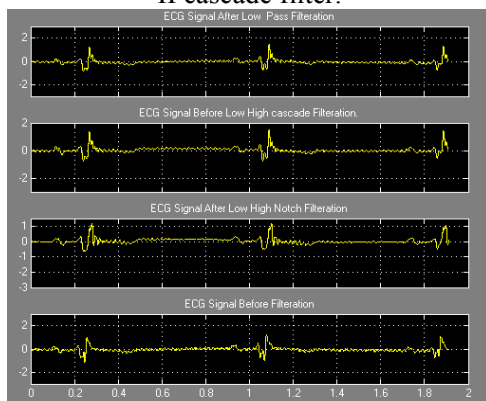


Figure 7.b ECG lead III signal of Chebyshev-II cascade filter.

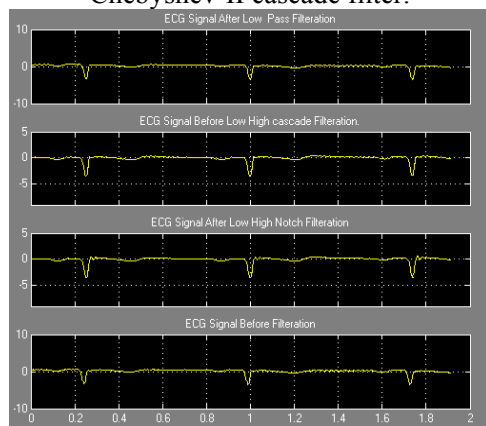


Figure 7.c ECG lead aVR signal of Chebyshev-II cascade filter.

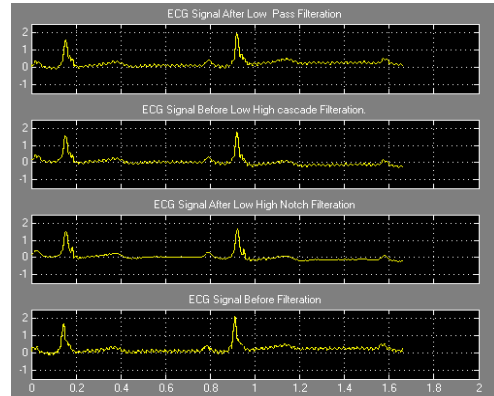


Figure 7.d ECG lead aVF signal of Chebyshev-II cascade filter.

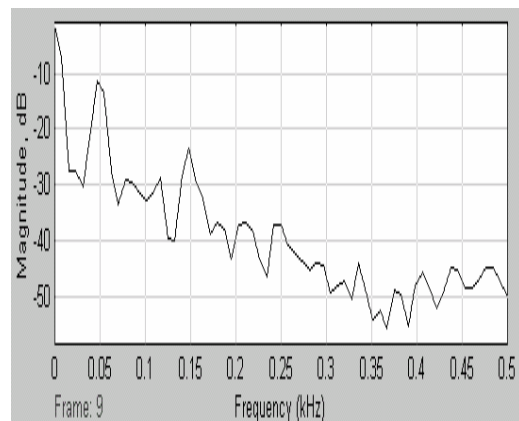


Figure 8.a Frequency Spectrum for Chebyshev II Filter Before Filtration of the ECG Signal

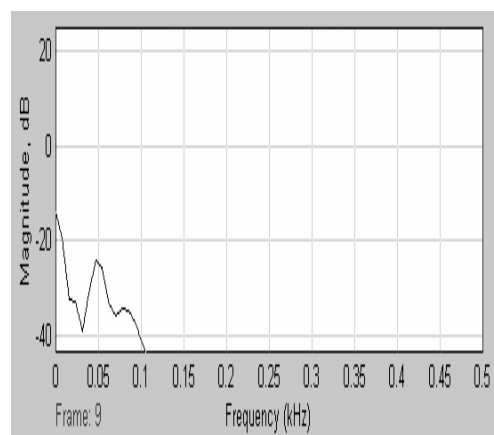


Figure 8.b Frequency Spectrum for Chebyshev II Filter after Filtration of the ECG Signal.

5 Conclusions:

With visualization of above results by appropriate design if the Digital Chebyshev type II Filter the noise in the ECG signal can be effectively reduced.

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