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Internal Sound Denoising for Traditional Stethoscope Using Inverse Chebyshev IIR Bandstop Filter

Alonzo Alterado[1], Adrian Vergel Viar[1] and Reynaldo Ted Peñas II, MScEngg[2],*
[1] *Bachelor of Science in Electronics Engineering, Pamantasan ng Lungsod ng Maynila*
[2] *Faculty, Electronics Engineering Department, Pamantasan ng Lungsod ng Maynila*
**Reynaldo Ted Peñas II: theengineerpen@gmail.com*

Abstract: A stethoscope is a medical device for auscultation, or listening to the internal sound of the body. Heart auscultation is one of the most fundamental ways to evaluate heart function. The stethoscope can be used to auscultate respiratory sounds, lung sounds as well as heart sounds, and diagnose most of the cardiopulmonary disorders and other diseases. One of the factor that affects the internal sound measurement and analysis system in the traditional stethoscope is the ambient noise. Without the presence of the ambient noise, specifically the second and third heart sound which range from 1 to 10 dB, the primary heart sound can be heard at a power of -2 dB.

This research proposes to simulate the removal of ambient noise in a traditional stethoscope using an IIR Chebyshev II Bandstop filter. The internal sound acquiring system includes a traditional stethoscope, jacks for PC connection, an amplifier, and MATLAB R2013a software. First, the system records the internal sound data from traditional stethoscope, and the recorded data will transmit into a computer by using jack connection and save it in .WAVE and mp3 file. The saved file will be filter using MATLAB software. Then, the processed sound signals are amplified for higher power. Overall, the whole process is the digital filter design and then amplified for more power.

This research aims to design and develop an Infinite Impulse Response (IIR) that can filter high frequency, since the second and third heart sounds range from 2 to 200 Hz which is higher than the first heart sound, to reduce these kinds of noise and make real-time digital signal processing. Also, this will increase the power of the first heart noise from -2dB to approximately 3 or 4 dB, which exceeds the mentioned range of the second and third heart sound. This filter aids the doctor in monitoring patient details accurately. Using this designed filter, patient can save his diagnosis and send to doctor for analysis.

Key Words: Traditional Stethoscope; Chebyshev II Bandstop filter; ambient noise; MATLAB R2013a software; Infinite Impulse Response

1. INTRODUCTION

A French physician named Dr. Lannenec invented the stethoscope in 1816, for listening to the internal sounds of the human body. It is often used to listen to respiratory and cardiac sounds. Since then, the application of the stethoscope has been rapidly growing as a fundamental tool for medical practices. The stethoscope can be used to auscultate respiratory lung sounds, as well heart sounds and diagnose most of the cardiopulmonary disorders and other diseases. However, some sounds from the stethoscope are below the threshold of audibility. Also, using the stethoscope to diagnose human's disorders need long term practices and experience. Sounds from the stethoscope suffer from noise because sound detection is going to be achieved by using a microphone which is sensitive to any sound as shown in Figure 1.

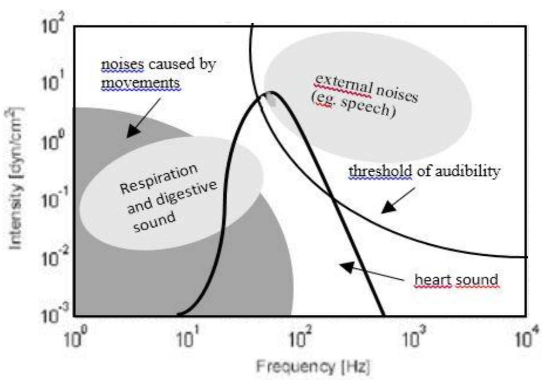

Fig. 1 Spectral Intensity of heart sound

In reducing certain frequencies, a bandstop filter is a good choice, since it selects frequencies to reject. A band stop filter is identified as a type of filter that allows the passage of a signal without alteration but attenuates the signal at certain frequencies. In other words, a band-stop filter simply attenuates an input signal at selected frequencies. A band-stop filter has two cut-off frequencies. It will pass above and below a particular range of frequencies whose cut off frequencies are predetermined depending upon the value of the components used in the circuit design. Any frequencies in between these two cut-off frequencies are attenuated. It has two pass bands and one stop band.

2. METHODOLOGY

2.1 Applied Process

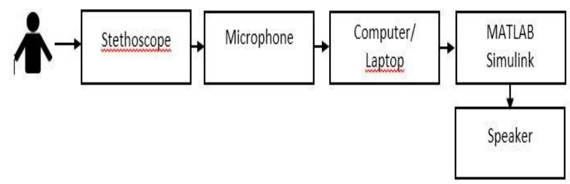

Fig. 2 Block Diagram of Heart Sound Simulation Process

Fig. 2 shows the how the hearts sound is going to be recorded then filtered, and how it sounds by the speaker.

To eliminate the ambient noise, the 6th order stopband filter is used as shown in Fig. 3 representing the: (a) pole/zero plot, (b) impulse response, (c) magnitude response, (d) phase response. The sampling rate is set at 44100 Hz in order to be heard at CD quality. Hence, the Chebyshev Type II bandstop filter to filter out the stopband at noise frequency, to make the heart sound the only sound heard by doctors and nurses.

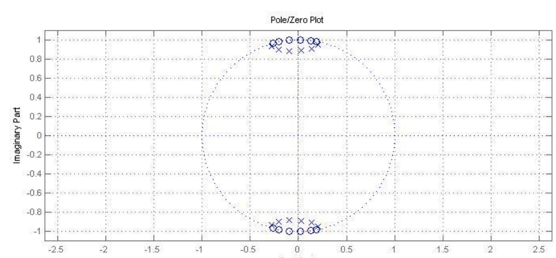

Fig 3(a). Pole/Zero Plot

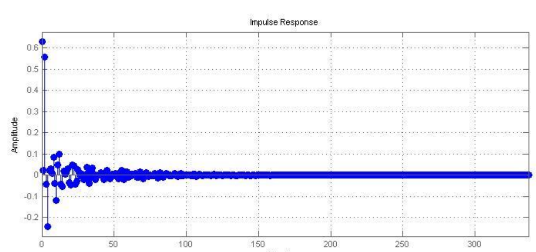

Fig 3(b). Impulse Response

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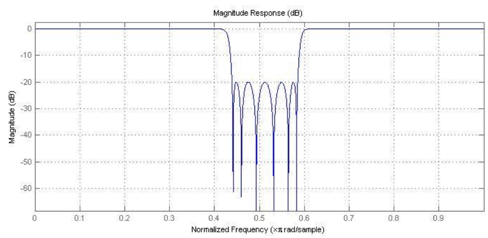

Fig 3(c). Magnitude Response

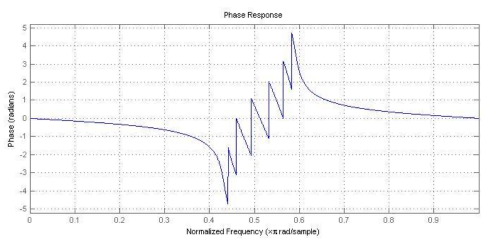

Fig 3(d). Phase Response

2.2 Algorithm

1. Record heart via stethoscope with mic hardware.
2. Save the audio file for simulation.
3. Open MATLAB, and use the designed filter to simulate filtering.
4. Display waveform. If the waveform characteristics of input to output are similar by correlation, save the filtered audio, if not, re-simulate.

2.3 Signal Characterization and Flow Chart

The Heart sound signal provided ae presented with an amplitude and frequency saved in a .wav file format. The signal is samples at a rate of 44100 Hz for CD sound quality with an 18-second duration at a bit-rate of 2822 kbps.

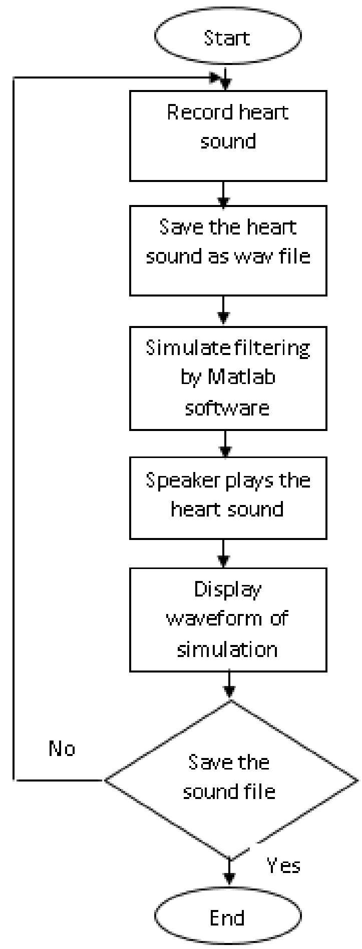

Fig. 4. Flow Chart form of the Heart Sound Filtering Process

2.4 Filter Design

In designing the filter, there must be a general transfer function with the specifications, specifically the stopband frequencies which are the frequencies of the noise.

$$\varepsilon_i = \frac{1}{\sqrt{10^{-0.1a_{stop}} - 1}} \quad \text{(Eq. 1)}$$

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$$\left|H_{L,n}\left[j\left(\frac{\omega}{\omega_0}\right)\right]\right| = \frac{\sqrt{\varepsilon_i^{\,2}\cdot C_n^{\,2}\left(\frac{\omega_0}{\omega}\right)}}{\sqrt{1+\varepsilon_i^{\,2}\cdot C_n^{\,2}\left(\frac{\omega_0}{\omega}\right)}} \quad \text{(Eq. 2)}$$

$$H_{\ln}(S) = \frac{\prod(B_{2m})\cdot\prod(S^2 + A_{1m}\cdot S + A_{2m})}{\prod(A_{2m})\cdot\prod(S^2 + B_{1m}\cdot S + B_{2m})}; n(even)$$

$$H_{\ln}(S) = \frac{[\sinh(D_i)]^{-1}\cdot\prod(B_{2m})\cdot\prod(S^2 + A_{1m}\cdot S + A_{2m})}{\left(S+[\sinh(D_i)]^{-1}\right)\cdot\prod(A_{2m})\cdot\prod(S^2 + B_{1m}\cdot S + B_{2m})}; n(odd)$$

Where:

ε_i = ripple factor

a_{stop} = stopband gain (dB)

$\left|H_{L,n}\left[j\left(\frac{\omega}{\omega_0}\right)\right]\right|$ = Magnitude Response (dB)

ω_0 = Center Frequency (Hz)

A_{1m}, B_{2m} = coefficients of the transfer function

n = order of filter

$H_{\ln}(S)$ = General Transfer Function in Laplace Transform.

3. RESULTS AND DISCUSSION

Using the Chebyshev Type II Bandstop Filter simulation in MATLAB, the heart sound signal is still at the same frequency while the frequency of the ambient noise is attenuated by the stopband. If the waveform is to be shown, the "freqz" function in MATLAB is used to show the magnitude and phase responses, and the correlation between the input and the output, as shown in Fig. 5.

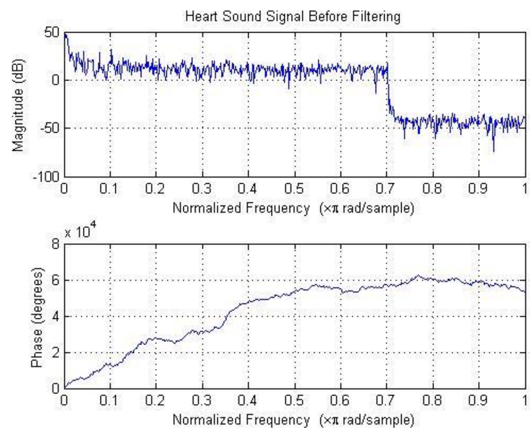

Fig. 5 (a). Heart Sound Signal before filtering

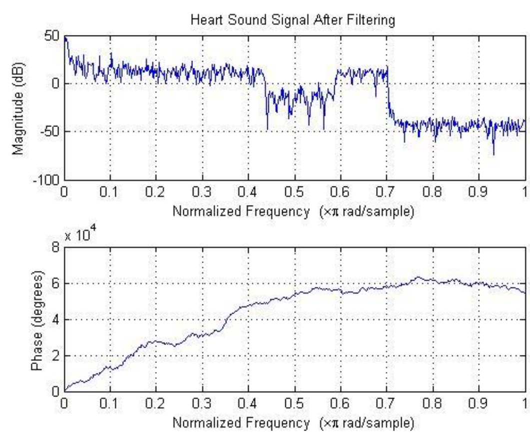

Fig. 5 (b). Heart Sound Signal after filtering

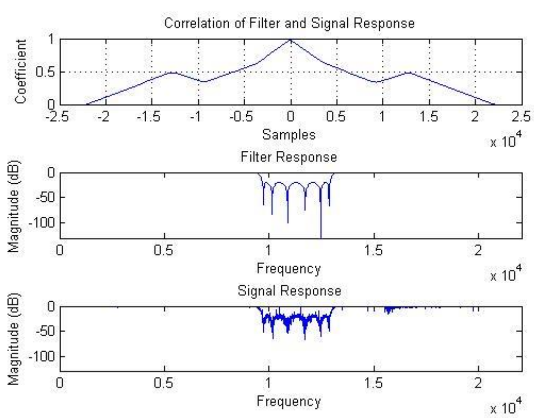

Fig 5(c). Correlation between input and output

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4. CONCLUSIONS

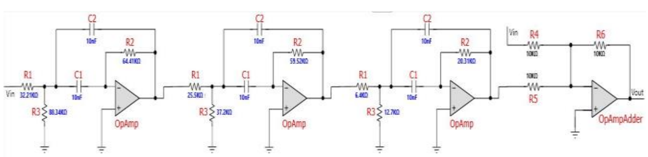
4.1 Findings and Recommendation

This research implemented a low-cost, improvised stethoscope with an improvised microphone inside its tube to record the heart signal directly to the PC/Laptop. The design provides a simulation using MATLAB software for the filtering process of the heart sound, using the designed Chebyhev Type II Bandstop Filter. By using the microphone, the heart sound was easy to stored using a built-in software in the PC/Laptop. In addition, the correlation results were close to one, meaning the filtering was successful.

Using these kinds of methods, can provide medical professionals to give correct diagnosis by analyzing sounds through studying signals and spectra.

In future, other filters like Bessel and Elliptic Filters can be likely used in these kinds of applications. Also, there are denoising techniques such as wavelet based de-noising, adaptive filter, Hilbert-Huang Transform empirical mode of decomposition for better accuracy and better advancement in future of cardiac auscultation.

4.2 Proposed Circuit



5. ACKNOWLEDGMENTS

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