

A Real-Time Heart Rate Signal Detection using an Electronic Stethoscope with Labview

Oktivasari P.^{1*}, Haryanto F.², Hamidah Salman A.³, Riandini R.⁴, Suprijadi S.²

ABSTRACT

Better accurate stethoscope measurements have been needed to diagnose heart problems earlier, monitor patients, and provide initial clinical data for physicians. This study aims to evaluate an electronic stethoscope for automatic identification of heart rate by monitoring Beats Per Minute (BPM) in real-time. In this work, a new design with a low cost electronic stethoscope is designed and implemented as a simple circuit for a replacement with conventional stethoscopes. This presented a low cost stethoscopes consisting of a preamplifier, low-pass filter, high-pass filter, microcontroller and Bluetooth. This simulation and experimental study was carried out for electronic circuit design testing. The condenser microphone transmitted the signal into the signal conditioning circuit, and amplified it from 10 to 30 times. The low- and high- pass filter circuit was with cutoffs of 180 Hz and 50 Hz, respectively. The result shows that the fourth-order Butterworth filter was the best filter, with a gain of 0.707 Volt, -3.01 dB, and 0.782 Volt, -2.137 dB, respectively. The real-time measurements using the system are not significantly different from the manual measurements, with around 2-5%, with a delay of 1.7 to 2 seconds. The results indicated that an electronic stethoscope system could provide suitable information for BPM value and could display heart sound signals.

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Keywords

Heart Instrumentation; Filter; Heart Rate; Real-time; Heart Sounds; Stethoscopes

Introduction

Cardiovascular disease is one of the leading causes of death in the world. Current technology has been trying to make a non-invasive tool for early diagnosis of the disease. The idea of an electronic stethoscope equipped with an automatic identification system of heart rate seems the appropriate solution [1] since this idea causes doctors to have more time and is expected to be easier [2]. Heart auscultation is the justification for cardiac performance, physiological and pathological information [3]. It provides reliable data on structural and functional heart defects using a simple, efficient, and cheap medical device such as the stethoscope [4]. The stethoscope is an acoustic medical device for checking sounds in the body, listening to the heart and breathing sounds. Normal heart sounds have a frequency range between 20 Hz to 200 Hz. The heart sounds consist of S1 and S2 related to valves.

¹MSc, Department of Physics, Institut Teknologi Bandung, Jl. Ganesha, Bandung

²PhD, Department of Physics, Institut Teknologi Bandung, Jl. Ganesha, Bandung

³PhD, Electrical Engineering Department, Institut Teknologi Bandung, Jl. Ganesha, Bandung

⁴MSc, Electrical Engineering Department, Politeknik Negeri Jakarta, Jakarta

*Corresponding author:
P. Oktivasari
Department of Physics, Institut Teknologi Bandung, Jl. Ganesha, Bandung
E-mail: ti2n_oktivasari@yahoo.com

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S1 and S2 are the “Lub” and “Dub” sound, respectively. The Lub sound occurs due to the closure of the Tricuspid, and Mitral Valves (Atrioventricular), while the dub sound is due to the closure of the Semilunar Valve (Aortic and Pulmonary) [5].

A conventional stethoscope has been generally used to hear the sound of a human heartbeat. Although the traditional systems have had the advantage of low cost and easy operation, conventional auscultation of the heart has been limited by several factors. The heart signal is a combination of high and low frequencies with low amplitude; thus, the interpretation factor of heart signal on conventional stethoscope is very subjective and much dependent on the physician’s experience, skills, hearing [6]. Therefore, it is necessary for sensors in the electronic stethoscope to have high selective sensitivity without any noise, which is fatal to the accuracy of the diagnosis. Therefore, it is vital to advance heart auscultation in order to determine the initial diagnosis of a heart condition.

The device utilizes an electronic tool to capture and process the heart rate signal and then transform it into an electrical signal, and later, the heartbeat signal will be visualized on a graph. Electronic stethoscopes converting acoustic sound waves into electrical signals must be amplified for optimal listening while processing [7]. In visualizing the heart rate signal using a series of electrical signal conditioners, the signal is sensed by the sensor and then pre-amplified by the amplifier circuit and filtered to the frequency according to the desired sound characteristics using a filter circuit. These analog circuits include pre-amplifiers, Low Pass Filters (LPF) with a 200 Hz cutoff frequency, and High Pass Filters (HPF) with a frequency cut of 20 Hz. LPF will pass signals with frequencies below 200 Hz and cut off signals with frequencies above 200 Hz, while HPF will pass the signal with a frequency above 20 Hz and cut off the signal with a frequency below 20 Hz [8], since

the main frequency components of the heart sound signal are in the range of 20-100 Hz. If the frequency was < 30 Hz [8], then it belongs to the category of the abnormal heart sound, as third and fourth heart sounds and the diastolic murmur of mitral stenosis [9]. The murmur with the highest frequency noise is aortic regurgitation, the dominant frequencies around 400 Hz [9]. Other sounds and murmurs have the major frequencies between 100 and 400 Hz [9]. Some of the literature used the optimal hardware of electronic stethoscope with a 2nd order filter [10]. Thus, this paper will implement a 4th order filter for a more optimal signal.

The filter circuit causes heart sound to have an incessant noise during heart disease examination. The signal conditioning circuit contains the pre-amplifier circuit, which is important to amplify the small voltage of the electrical signal output from the mic-condenser, then the HPF circuit. The output signal from the signal conditioning circuit has been processed by Arduino to be sent to a Personal Computer wirelessly using the Bluetooth HC-05 module. The software used to display the results of heart rate detection is LabVIEW. In addition to displaying heart rate signals, programming in LabVIEW is also used to show BPM and save the results of detection. Heart rate has been commonly utilized to characterize alterations in heart rate and autonomic cardiac function and can also be used for the diagnosis of lung cancer.

Material and Methods

An intelligent stethoscope systems have been able to calculate BPM values and store signal patterns, so that recorded heart signals can be shared with other doctors and lead to making process easier and more accurate. A system, which was capable of performing such operations, was presented here. To do the BPM monitoring system based on LabView, a low-cost electronic Stethoscope and the components were used as shown in Figure 1.

The electronic stethoscope could transmit

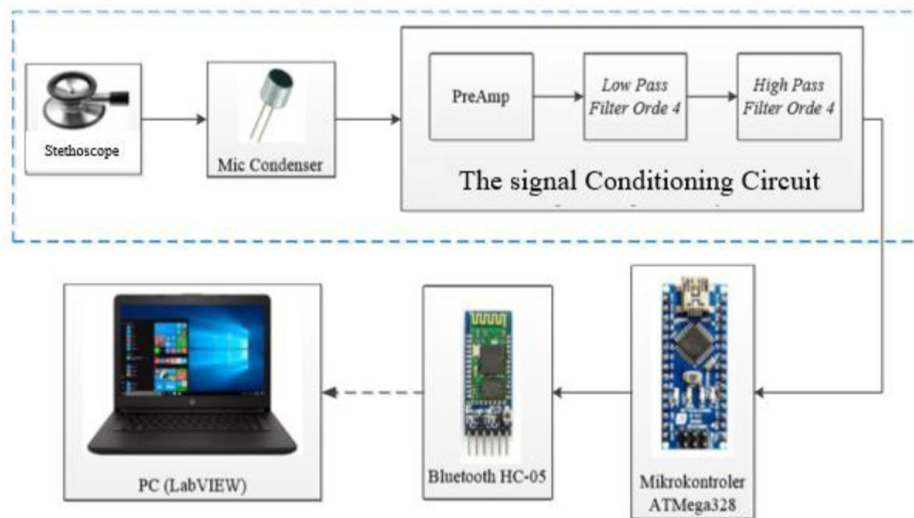


Figure 1: A schematic of Heartbeat Signal Detection System in case studies

the heart sound wirelessly using Bluetooth seen in Figure 1. The result was displayed with the LabVIEW interface to a graphical code. The heart sound was captured by the membrane's stethoscope and passed to the mic condenser and then amplified with a gain of 10 by the preamp; then, it was followed by an anti-aliasing low pass filter using CA 3240 with a cut-off frequency at 20 Hz and 200 Hz.

Hence, this system will be used to monitor BPM values for relaxing and exercise conditions. There are several pathologies from the heart that can be used based on this BPM value, especially. In the future, BPM value will be used to indicate clustering on this system. Even though there are several pathologies for study, only arrhythmia and normal cases were selected as a case study. The grouping can define types of diagnosis and analyze the level of BPM in any condition. This testing starts with sampling the gender, age, and condition parameter.

Case study on Pre-Amp Circuit

Pre-amp circuits are the most common type of electrical equipment in the electronic stethoscope, served to strengthen the sound signal

from the condenser mic. The principle of pre-amp is the amplification of heart sound with a gain of 10 by modification of the resistor and capacitor circuit. The correct operation of pre-amp equipment is essential to ensure that the device catches the sound of the heart and proceeds it to the filter circuit. The purpose of test the pre-amp circuit is to see the signal output on the computer and oscilloscope. While amplifying, the signal can be saved for further processing on the computer in "wav" format. In this case, quantitative analysis of sound measurements represents types of abnormalities in the heart, which are depending on the rhythm, frequency, and intensity of the sound.

Case study on Filter Circuit

The filter is the equipment for limiting the frequency value forwarded to determine the type of signal, which is captured through the electronic stethoscope. The first stage for making a heart signal detector is determining type of filter, which is suitable for the signal conditioning circuit so that the heart rate signal has a good shape and is visible in S1 and S2 patterns and the best filter is the 4th order Butterworth filter. The calculations are also

carried out on the signal conditioning circuit. After creating the circuit, the next method is testing the circuit with the function generator and oscilloscope. In the case of an electronic stethoscope, filtering is performed for heart sounds at normal frequencies, with a cut-off frequency at 20 Hz, and 200 Hz. An overview of the proper filter usage is vital for this tool because, without a filter, the heart sound will not be recorded by good intensity.

Case study on BPM System

Heartbeat can display how much our bodies weight. The results of a heart rate count can be used as a guide to exercise, which should be done in the future. In an emergency, the heart rate can also show whether the heart pumps enough blood. Cardiovascular disease has still been the main cause of death in the world. People with coronary heart disease has been younger due to an unhealthy lifestyle. Therefore, check of regular heart health and an expert system are needed in order to detect heart conditions early at a low cost. This tool has been equipped by a BPM monitoring system automatically and calibrated by manual measurement. In the BPM, measurement study begins by setting a threshold so that the stored signal is in the best condition. There will be the difference in BPM values for age conditions and the same treatment between women and men.

Results

Safety and performance testing are required to ensure the results and reports, which are accurate, reliable, and safe for delivering treatment and diagnosing process. Testing was performed in two ways, including software and hardware. Testing has been done to validate the prototype and check the system failures. Filter characteristics with cut-off frequencies have been examined by applying a 0.4-1 V signal with a frequency range of 20 Hz to 200 Hz from the signal generator as input.

As shown in Figure 2, it is the highest within

the 4th order bandwidth. Based on the data, there was an estimated 3dB drop at the cut-off frequency of 150 Hz. This condition has shown that applying order four and the type of Butterworth filter, which had the highest frequency of attenuation compared to the Chebyshev filter and Bessel filter, were appropriate. According to the values of the input and output of data's amplitudes (peak - to - peak), the signal has been amplified. Besides, it checked and used software testing to determine the optimal response and choose the best filter. This was performed by comparing the responses of the 1st, 2nd, and 4th order of LPF (cut off of 200 Hz) and HPF (cut off of 20 Hz) Butterworth filters, as noted in Figure 2, although Butterworth was known to eliminate the murmuring sound. Since the frequency response of the Butterworth filter was maximally flat, and there were no-ripples in the passband. Besides, it was rolled off towards zero in the stopband.

The 4th order of results obtained from high pass filter simulation, which used the response of the Butterworth filter, showed a response similar to 2nd order, but the response was sharper, as shown in Figure 2a. Based on the simulation, as shown in Figure 2, the 4th order of the HPF Butterworth filter provided a response that was similar to 2nd order but sharper with gain -2.137 dB, 0.782 Volt. Then the best choice for HPF is the 4th order. This condition was also applied for LPF with gain-3.01 dB, 0.707volts, as shown in Figure 2b.

The signal of conditioning circuit in a heart rate detector, which used an electronic stethoscope, can convert the heartbeat sound into an electrical signal. The heartbeat signal can be amplified and filtered. However, there was a difference between the actual and measured voltage values in the inverting amplifier circuit. Then, the output signal of the inverting amplifier obtained from a signal generator with 400 mV and 150 mV can strengthen from ten to thirty times, as seen in Figures 3a and 3b. Moreover, the low pass filter circuit of the 4th order, with the 200 Hz cutoff frequency, was

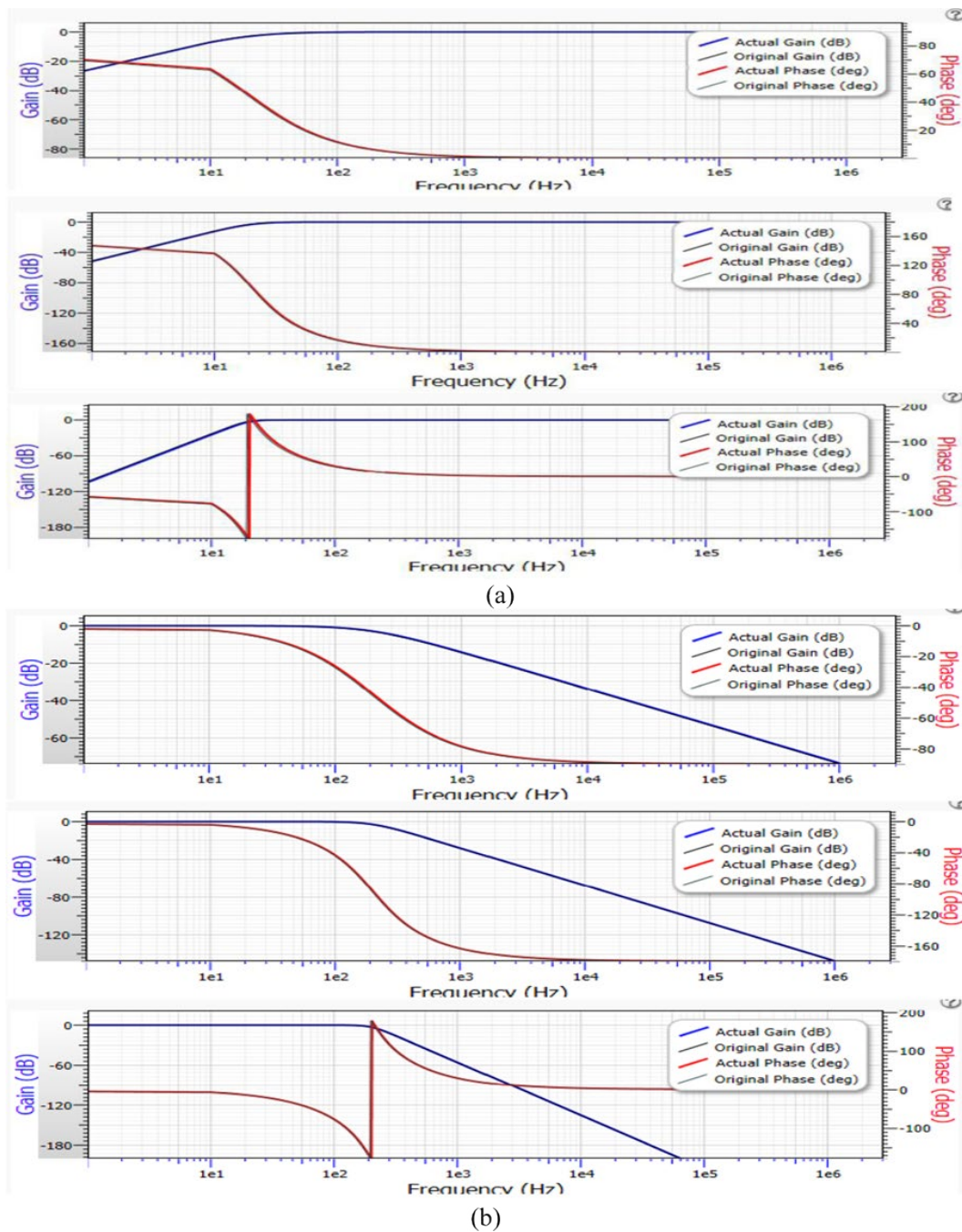


Figure 2: A Response of 1st, 2nd, and 4th order in case studies: a) Response of HPF of 1st, 2nd, and 4th order, b) Response of LPF of 1st, 2nd, and 4th order

tested by two sine wave inputs of 1 V, with frequencies of 200 Hz and 20 Hz, producing outputs, which showed a signal truncated at 180 Hz and the signal cut at 50 Hz, respectively shown in the Figures 3c and 3d.

As illustrated in Table 1, the results show inverting circuit testing and then comparing it

with the theory. The resulting output voltage is not much different from the theory, which explains the correct selection of resistors and capacitors used, although it has still had a tolerance of 5%.

The heart sound data was graphed in real-time using LabView to interface with the Ar-



Figure 3: Output Signal on the Oscilloscope and LabVIEW in case studies: a) The Inverting Amplifier Circuit Output Signal with 400mV, b) The Inverting Amplifier Circuit Output Signal with 150mV, c) Output Signal Order 4 LPF Circuit 200 Hz Cutoff, d) Output Signal Order 4 HPF Circuit 20 Hz Cutoff, e) Heartbeat Signal Results in the LabVIEW Interface

Table 1: Measurement Results in Case Studies (Output Voltage)

The First Amplifier Inverting			The Second Amplifier Inverting		
Input	Output	Theory	Input	Output	Theory
100	-0.95	-1	8	-1.1	-1.2
200	-1.29	-2	10	-1.4	-1.5
300	-2.9	-3	12	-1.6	-1.8
400	-3.8	-4	14	-2.05	-2.1
500	-4.8	-5	16	-2.3	-2.4

duino. LabView could read the voltage level on an Arduino analog pin and then plot the data. The heart rate was measured by calculating the predominant peaks that occurred in the data and then averaged the results over time to read Beats per Minute (BPM). Controls of the user interface were included in the system to express the BPM reading and easily the program. Figure 3e shows the LabView interface on PC to detect BPM from the heart, and the user could save the result of the heartbeat signal. The heartbeat signal captured has still been S1 and S2, while S3 and S4 have not been detected because the frequency was very small.

BPM measured in LabView had a slightly different value than manual BPM calculations because the program measured BPM on LabView used the manual threshold to have peak signals like heart rate parameters so that the reading results were less accurate. Based on the results of BPM calculations, there was not much difference between LabView system and manual testing, around 2-5 %. The women had a higher number of BPM than men, as seen in Table 2. The threshold level was determined automatically by blocking the display area of the signal. However, if there was a change in the baseline, the changing area would be edited manually, as data 585 in Table 2. Test the Bluetooth connection to the LabView system had a delay with the average 1.7 - 2 seconds. Furthermore, filtering techniques are still needed in the system to make more accurate

results, and the signals produced in this system are only visible patterns S1 and S2, depending on the hardware used has still been in the range for normal heart frequencies.

Discussion

The filter circuit is an essential system in an electronic stethoscope system. The filter circuit influences the accurate signal pattern. This result of pattern is shown in Figure 3e, which presented the normal signal, S1 and S2. High signal frequency with > 200 Hz and also low signal frequency with < 20 Hz have indicated murmurs, and abnormal heart sound S3, S4 and the other important circuit is the pre-amplifier. To design, a good pre-amplifier circuit must be precise with determining of frequency expected. Therefore, it is necessary to get the serious, accurate design of stethoscope hardware in the pre-amplifier and filter circuit. To get realtime results from electronic stethoscope measurements, we need a system without delay, and the accuracy of the results of signal is similar to the original heart signal.

Conclusion

Acquiring results in design of electronic stethoscope discussed case studies indicate a need for filter circuit and amplifier circuit fitting the electronic component used, to get the heart signal results without noise. In this study, a low cost electronic Stethoscope integrated

Table 2: Measurement Results in Case Studies (Comparison of BPM measurements)

Gender/age	LabView System	Manual	Threshold
Women/20	78	80	200
Women/21	87	90	200
Women/19	98	94	185
Women/20	90	90	188
Men/22	74	75	185
Men/20	67	69	585
Men/21	70	73	185
Men/22	74	74	185

with BPM monitoring system has been developed and tested to provide real-time heart rate signal. The signal conditioning circuit can amplify the signal from 10 to 30 times; the 4th order low pass filter circuit with cutoffs of 200 Hz and 20Hz produces a cutoff of 180Hz and 50 Hz, respectively. An electronic Stethoscope system can provide suitable information of BPM value for a preliminary diagnosis of heart and heart signals.

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Conflict of Interest

None

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