Low Noise Electronic Stethoscope

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ABSTRACT

This paper presents a device which is capable of extracting, processing and displaying acoustical data gathered from patient’s body. Stethoscope is a medical device, introduced 200 years ago and still widely used by doctors to listen cardiac sounds to detect various body disorders and improper working of heart valves. The introduction of electronic stethoscope in the modern era has improved the efficiency of pulse detection. The biggest disadvantage of acoustic stethoscope is the output is very low and muffled, improper to use in noisy environment. The electronic stethoscope provides low noise environment with much efficiency, thus more accurate in defining the cardiac signal. The major advantages of electronic stethoscope are improved accuracy, data storage for future use, display of cardiac sound variation on monitor, capable of analysing sound data of irregular heart rate pattern with greater efficiency.

KEYWORDS: Cardiac signal, Acoustic stethoscope

INTRODUCTION

Stethoscope is an important tool in the medical world. In a survey, people who already have graduated from medical school have low stethoscope skills. During examination, it was found that on an average, they could name only 15-20 percent of common abnormal heart sounds [1]. Listening to cardiac sound with stethoscope is part of regular check-up and for diagnosing heart problems. Learning to use acoustic stethoscope is not easy. The reasons behind this are sound is low and muffled and a cardiac sound lasts for less than a second [2].

Listening to cardiac rhythm can tell us about various disorders such as rapid heart rates can occur due to anaemia, abnormal electrolyte levels or thyroid hormone levels while slow heart rates can occur due to hypothermia, low body temperatures etc.

Like many other devices, acoustic stethoscope has undergone various technological changes in order to ensure that doctors don’t find any trouble to diagnose heart problems [3]. Acoustic stethoscope in which the diaphragm capture the cardiac signal through chest piece and travel through the hollow tube to the listener’s ear, produces low sound levels and making it difficult to hear every beat whereas digital stethoscope, that works similar to acoustic stethoscope, except the sound is converted to electrical signal which can be further used to generate beats per minute, record for future use, observe the variation in cardiac signal by plotting the sound waves graphically, it also amplify cardiac signal for better hearing[4,5,6].

The major components used in the hardware designing of digital stethoscope are a low noise preamplifier, sensor, monitor, flash memory, and microcontroller unit.

Block Diagram:
**Fig. 1: Block diagram of electronic stethoscope**

**Microcontroller unit:**
It is used for converting analogy signals captured by acoustic sensor to digital signals using ADC port pins by signal processing. It has signal processing interface, user interface, real time audio processing, and flash interface thus providing reliable connections among the various components.

**Sensor:**
The simplest way to capture cardiac signals is by using condenser microphone attached to the acoustic amplifier, diaphragm, but this introduces noise which can interfere during the signal processing by microcontroller. It is necessary to remove the noise from the captured signals for greater efficiency. Thus a preamplifier circuit is required which amplifies the required signals and remove unwanted signals i.e. noise. The output of the acoustic sensor is connected to preamplifier circuit for amplification and removal of unwanted signals.

**Flash memory:**
It is used to store the output that can be used in future. An external flash memory is used when the flash memory embedded in microcontroller unit is not sufficient to store outputs, therefore retaining data in the absence of power supply.

**Preamplifier Circuit:**
The output by the condenser microphone is of the order of millivolts [7,8]. It becomes challenging for the microcontroller to work in such a small output operation as well as difficult for the human ear to hear the output produced by such output.

The figure shows the preamplifier circuit with the following specifications.

1. Power is 12 volt
2. Gain- is 27DB
3. SNR is 127DB at 1.5 KHZ
4. Overall gain is A= 1+(R6/R4)
5. Noise output- 1.10 microvolt
Fig. 2: Two stage emitter coupled preamplifier circuit

It is a two stage emitter-coupled amplifier that operates on series voltage feedback. It has low noise levels, high input impedance. The output of the transistor was passed through capacitor to remove the DC offset which hinder during signal processing.[9]

(a) output of Preamplifier circuit. (b) Analog analysis of the amplified output.
The input signal of 110 millivolts produced the output voltage of 2.6 volts which is appropriate for human ear as well as for signal processing by microcontroller. The noise produced at the output is approximately 1.10 microvolts by the preamplifier circuit which was found during noise analysis. Therefore the circuit can be used as a preamplifier circuit in electronic stethoscope.

**Fig. 4:** Noise Analysis of preamplifier circuit

**Digital to Analog Circuit:**

In order to listen the recorded waveforms or real time waveforms, through headphone, it is necessary to convert digital signals to analogue signals. Therefore, the digital to analogue converter was implemented. D/A converter have an op amplifier.

**Fig. 5:** Digital to analog converter (D/A) digital signals to cardiac analog signals for headphone.

**Heart Waveforms:**

Heart rhythm disturbances can occur due to improper functioning of inner body environment reducing heart’s ability to perform efficiently. This is because the ability to absorb oxygen depletes that results, heart to beat faster or slower. Therefore obtaining cardiac waveforms will define body or heart disorders more accurately. When two heart waveforms were analysed using electronic stethoscope, produces the following output.
The fig. 6(a) shows the heart waveform of a normal heart rhythm and fig. 6(b) shows the heart waveform of a person suffering from rheumatic fever. One can clearly state the difference between the two waveforms. The latter waveform is beating faster than the first one. Also the latter heart beat lasts longer than the first waveform. Thus it is clear that a heart waveform can tell about the disorders a person is suffering from, electronic stethoscope becomes a reliable tool that can be used easily by a doctor to detect various disorders.

**Operation:**

*Step 1* – The capturing of sound by condenser microphone attached with chest piece.
*Step 2* – Amplification of sound by preamplifier for further processing.
*Step 3* – Conversion of analog signal to digital signal by microcontroller. Recording of data for future use.
*Step 4* – Conversion of digital to analog signal for further listening from earphone/headphone.

**Real Time Plot:**

Arduino software with a defined program was used to plot the real time cardiac signals by placing the chest piece over the heart, the signals were then processed by the Arduino and the output was shown. The MATLAB program was also designed to determine the beats per minute (bpm).
Under normal conditions, heart beats 60-100 times per minutes while under abnormal conditions the rate changes according to the disorder, it may decrease or increase.

**Future Scope:**

Wireless electronic stethoscope and development of the mobile application can lead to the device come in handy and can be used by the patients to send data to the professionals. The device on internet of things (IOT) platform can be used to share the data with the doctors for further analysis. The device can also be designed for measuring blood pressure. The combination of cardiac signal data and blood pressure data could be used for the general analysis of the disorder. Development of the application can help in sharing the patient’s data to the doctors across the world, where doctors and patients will be provided with the login id. The data can be saved in the mobile application, using cloud storage.

**Conclusion:**

The device can perform following functions.

- Capture cardiac signals using condenser mic attached with chest piece.
- Record and playback cardiac sound.
- Display real time heart waveforms on monitor.

Apart from processing cardiac signal, the device can also be modified for measuring blood pressure and lung disorder. It can also be modified for detecting flaws in a working machine without dismantling the machine such as loose screw or broken machine part. The electronic stethoscope has many advantages over acoustic stethoscope such as amplified cardiac murmur, low output noise environment, display cardiac waveform, storage option. There are disadvantages concerned with electronic stethoscope such as

- Heavier
- Costly
- The output may be affected by nearby electrical components.
- It may damage due to mishandling.

There is always a room for improvement in technologies. SNR can be improved for the preamplifier circuit, increasing the efficiency of the output. The algorithm can be designed which may define and classify the cardiac disorder based on the captured cardiac signal. It can also be made handy thus allowing non-professionals to use it efficiently for detecting minor body disorders and for regular body check-up. The electronic stethoscope can be used by professionals who wishes to record data for future use, or by the professional who finds it difficult to hear the low muffled cardiac sound. It is a reliable device that can be used widely in medical science.

**REFERENCES**

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