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Digital Stethoscope: Electronic Auscultation and Processing

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Abstract: **-- Stethoscope is one of the basic diagnostic tool used in the medical world. Traditional auscultation of heart, gastrointestinal and lungs sounds requires good listening skills and comes with experience. An attempt is made to modify the acoustic stethoscope in order to ensure efficient auscultation and diagnosis of a patient. The electronic stethoscope enables signal storage, processing, filtering and analysis of signals. It offers an advantage of amplification, noise reduction over the classical stethoscope. The BPM count predicts the abnormalities in the heart and can detect diseases. Through the GUI, a user can control different functionalities of the device. This paper aims to design and develop an electronic stethoscope with minimum complexity and lower cost.**

Keywords: Raspberry Pi,Electronic Stethoscope, Signal Processing, biomedical engineering, 3D Printing

I. INTRODUCTION

In a normal acoustic stethoscope, a diaphragm is used to collect the sound and convert it into acoustic pressure wave. The pressure waves coming from the diaphragm are transferred through tubes to the ear piece. In this process, a considerable amount of noise is added during the process. To eliminate the addition of noise during transmission, we convert the sound waves to electrical signals just after the chest-piece using a microphone.

The electrical signal can be modified in the transmission phase. The signal can be refined using filter circuits to improve the quality of sound. The amplitude of the signal can be increased to improve the intensity of the sound. The signals can be displayed as well as saved in an external memory for continuous monitoring of the health of patient or for future references. The refined electrical signal can be later be reconverted to sound using a head phone to ensure the conventional diagnosis process is not hampered.
The electrical signals are converted to digital form using Analog to Digital Converter and the digital form is sent to the Raspberry Pi for the processing. The signals are then analyzed in the Raspberry Pi and then are displayed further on a screen. The screen also displays the GUI generated for the user to operate the different functionalities of the system.

Various diseases and problems like Heart rate and Murmur sound produced by heart after systole or diastole can be used to detect problems like Bradycardia, Tachycardia, Sinus Arrhythmia and improper functioning of valves such as aortic stenosis, mitral regurgitation can be detected by heart rate and Murmur sounds produced by heart after systole or diastole [1].

II. HARDWARE AND DESIGN

2.1 Electronic Design

The circuitry used for an electronic stethoscope is shown in the figure. This whole setup is placed inside the 3-D printed box.

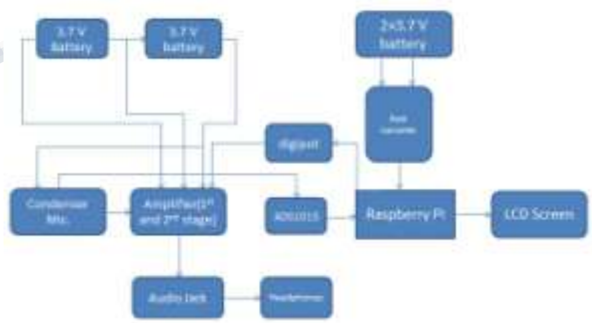

Figure 1: Basic Block Diagram of the setup

In this design, a normal stethoscope diaphragm is integrated with an electret condenser micro-phone, an amplifier, anADC, Raspberry Pi, LCD Screen, Buck converter and four 3.7V Lipo batteries. The signal from micro-phone is supplied to two stage amplification circuit which performs the basic function of amplification, filtration, increasing the driving capability and control of audibility. Digital Potentiometer has been utilized in the circuit for volume control through the GUI. The output volume control is done by changing the gain of first amplifier by giving commands to Digital Potentiometer. Digital Stethoscope thus overcomes the limitation of classical stethoscope as intensity of some body sounds is below the threshold of audibility.[1]

The output from amplifier circuit can be heard from headphones.

The microphone output is also supplied to ADC (ADS1015). ADS1015 has been as chosen as it offers an advantage of high sampling rate (128 to 3.3ksps)[2]. It is interfaced by I2C interfacing, also Heart and lung sounds closely lie between 30 to 700Hz and the sampling rate is close to 3.3KSPS which is approximately 4.5x sampling. Thus, output will be sampled easily and accurately.

Raspberry Pi is a credit-card sized computer. It's qualities makes it a very versatile controller capable of handling an array of sensor data values while controlling various input or output devices like mouse, LCD screen, Motors etc. It is used as a main tool to control whole process in our project. It takes microphone sensor readings through the ADS1015 and display them in graphical format.

LCD screen is interfaced from Raspberry Pi by SPI communication. It is a Resistive 320*240 pixels TFT touchscreen. It is used to obtain results and waveforms of signals.

Sound saved can be played back by using MCP4725 DAC. Output from DAC is supplied to same amplification stages as mentioned before. It is a single channel, 12-bit device. It is interfaced by Raspberry Pi through I2C communication. It has three modes of operation: Standard, Fast and High Speed.

2.2 Mechanical Design

To ensure proper sound collection we use the chest-piece of the stethoscope only. It has a diaphragm which when placedon the patient, the body sounds vibrate the diaphragm, creating acoustic pressure waves which travel up the tubing to the microphone.

The loss proof transmission of sound and the incorporation of the microphone in the transmission media were the primary criteria for the selection of tubing and microphone.

For better sound transmission and isolating external noise, the tubing should be made up of thick material preferable with a large internal bore. The microphone and the stethoscope chest piece were inserted from either side of the tube thus ensuring minimal sound loss.

Chest piece tube is kept at least possible distance from the electret microphone. Such a configuration was chosen so as maximize the efficiency of sound to electrical energy conversion.

Figure 2: Chestpiece, Tubing and Microphone assembly

Final device was designed to be light and portable. The design of the box was made in Autodesk Inventor and then 3D printed using PLA (Poly Lactic Acid) material.

Figure 3: Final assembly with 3D printed casing

III. INTERACING AND PROCESSING

Programming for the GUI is done using Tkinter library available in Python. The figure shows the block diagram of program flow in the GUI created.

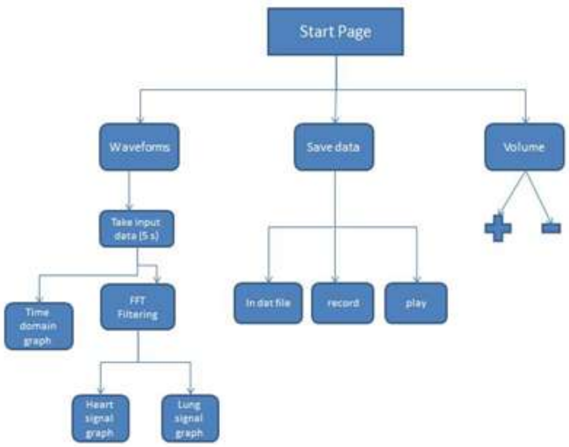

Figure 4: Block Diagram of GUI

The GUI main page has four buttons. View waveforms button will enable us to take input data and present it in the form of waveform. Data is saved in .dat format using the save button.

In the view waveform window, the type of domain- time or frequency has to be selected. Then, select the kind of signal – Heart sound, Lung sound.

Figure 5: GUI created

Data is saved in a .dat file using save data button. Here sound can be saved and played back using MCP4725 DAC.

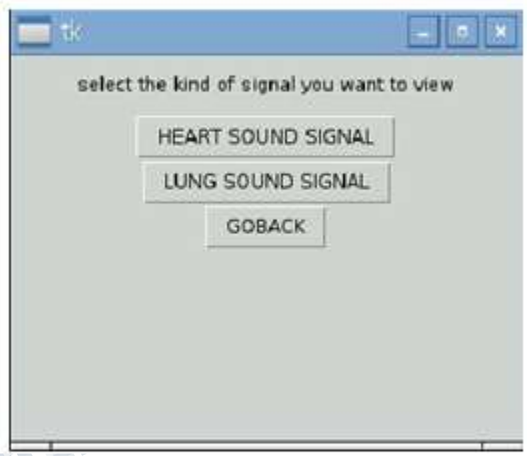

Figure 6: GUI

3.1 Filtering by Fast-Fourier Transform

Noise is filtered out in frequency domain. The signal is converted from time domain into frequency domain. For frequency domain transformations, Fourier transform algorithms are utilized.

Figure 7: FFT Filtering

3.2 BPM Calculation

The BPM level of the patient is determined using filtered Heart waveform. For determining it, BPM calculation

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algorithm was developed. The BPM gives the number ofcontractions of the heart per minute.

The bpm value for a body depends on the physical, physiological and pathological conditions of the body. Activities such as physical exercise, sleep, anxiety, stress, illness, and ingestion of drugs affect the BPM of the body. The BPM count as well as the abnormalities in the heart rate of the patient can be used to predict the presence of disease.

3.3 Time Averaging

Time averaging is done to improve the quality of the waveform. Averaging the digitized signal will reduce thenoise strength but not the signal strength so the SNR value is enhanced and a better output is obtained.

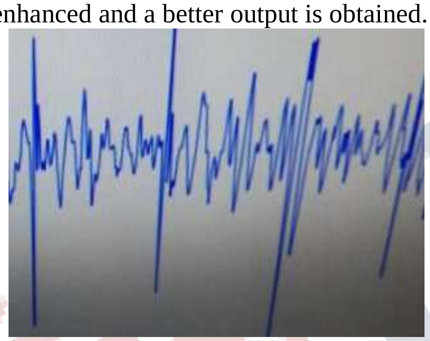

Figure 8: Heart signal waveform with time averaging

IV. RESULTS

The figure shows the heart beat signal before processing.

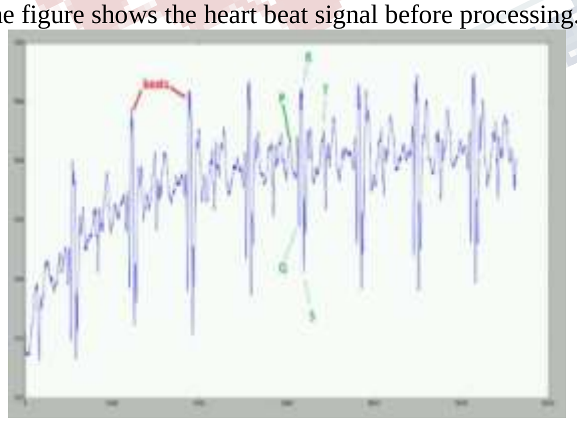

Figure 9: Heart beat signal before processing (P,Q,R,S,T shows different sections of heart waveform)[3]

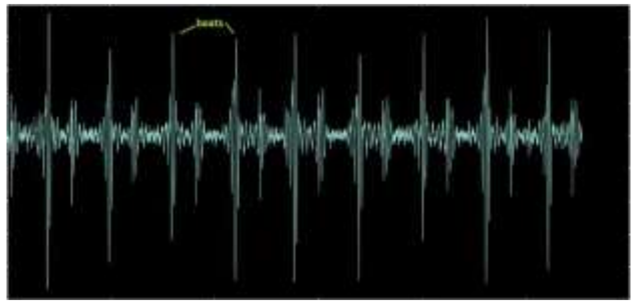

Figure 10: Heart beat signal after processing (with FFT Filtering)

V. CONCLUSION

This project was an attempt to create a digital stethoscope. Most of the electronic stethoscopes available in the market are very costly. We have attempted to improve the functionalities of the traditional acoustic stethoscope to bridge the gap between the electronic stethoscope and it acoustic counterpart. The product is a basic attempt and so further size reduction and other functional advancements can be still be incorporated. The product is just a beginning to provide a technologically advanced version of the diagnostic tool to prove beneficial to the entire healthcare community.

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ANALYSIS

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