Heart and Lung Sound-sensing shirt

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Introduction

Objective

According to the World Bank and WHO, half the world lacks access to essential health services and 100 million are pushed into extreme poverty because of health expenses. There are many factors for this such as the lack of good doctors and the poor quality of medical diagnostic devices. Often, this causes people to travel large distances to talk to a doctor, which can be hard at times. This inspired us to take on a senior design project that may potentially solve this problem. Our goal is to design and build a shirt that is capable of detecting heart and lung sounds which a user can access on his smartphone and then send to a professional doctor.

Background

Many people may be stressed, sometimes even afraid to go to the doctors, even if it's just for a checkup. In many countries, people do not have access to quality healthcare and often have to travel large distances meet a doctor. Even after investing time and money, they might not be able to get good quality treatment. In this case, many people would benefit if they had were able to consult a doctor without physically going there. Therefore, this project will provide convenience for many people and cause them less stress when the need to see a doctor arises.

In the market, there are shirts that can detect a user's breathing and heart rate. However, this shirt will detect the sounds of both the heart and lung, and by implementing a Bluetooth feature for communicating with a smartphone, the results will be available to be sent to an expert.

High-level requirements

- Microphones must be placed at the correct locations on the body.
- We must make sure there are no noise frequencies to provide best results for the doctor.
- The sounds must be transmitted via Bluetooth to the user's phone, so that it can be delivered to a doctor for analysis

Design

Block Diagram

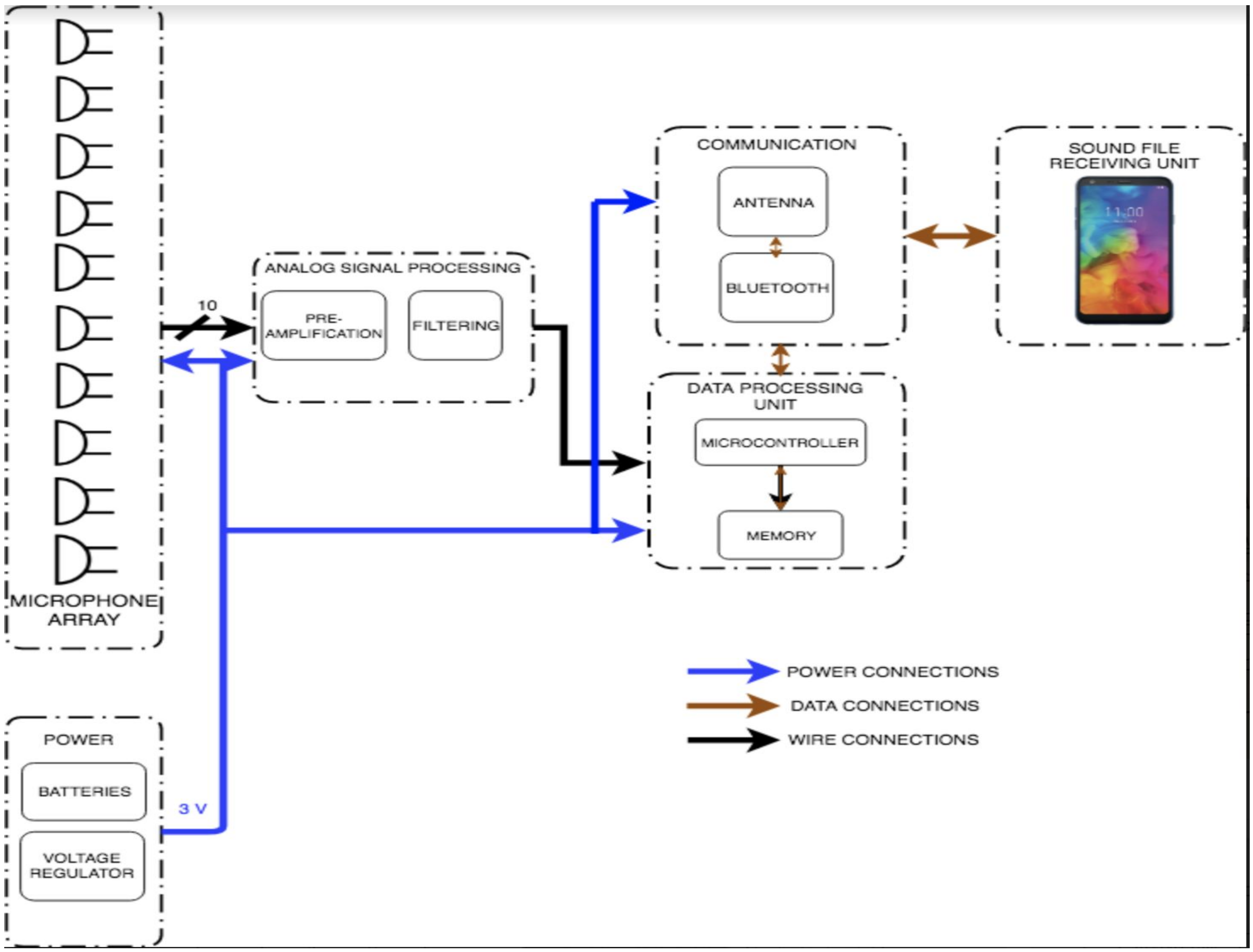

Figure 1: Block Diagram

The Block diagram in the above figure demonstrates how different units in the system interact with each other to fulfill the high-level requirements of this project. The ten microphones will be placed at different positions on the shirt along with independent Signal processing units. The output signal from each of these Signal Processing Units will be transferred to a Microcontroller for processing the data and transferring it to a smartphone via a Bluetooth module. The sound files from the system will then be made available to the user on a smartphone and can be sent to a doctor for analysis.

Physical Design

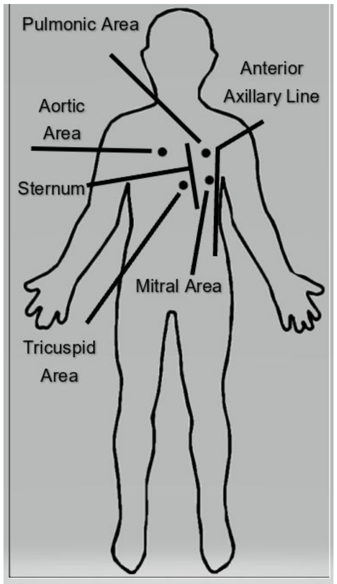

Figure 2: Physical diagram

The figure above demonstrates the locations of six of the microphones along with their independent Signal processing units on the chest and abdominal area of the shirt to detect the heart and lung sounds. Four of the microphones are going to be placed on the back across the Aortic Area, Tricuspid Area, Mitral Area and Pulmonic Area.

Functional Overview

Microphone Array

Microphones are used in our system to sense the heart and lung sounds. The microphones will be placed at 10 different positions on the shirt, where the doctor's primarily hear the heart and lung sounds through their stethoscopes. Statistical analysis showed that the major concentration of energy, for both first heart sound (S1) and second heart sound (S2), is below 150 Hz which may indicate that both sounds are caused by vibrations within the same structure, possibly the entire heart. However S2 spectra have greater amplitude than S1 spectra above 150 Hz, which may be due to vibrations within the aorta and pulmonary artery. In subjects with healthy lungs, the frequency range of the vesicular breathing sounds extends to 1000 Hz, whereas the majority of the power within this range is found between 60 Hz and 600 Hz. Other sounds, such as wheezing or stridor, can sometimes appear at frequencies above

2000 Hz. Based on this data, the microphone should will be able to detect sounds within the frequency range 20 Hz - 2500 Hz. The analog output from the microphones should be pre-amplified and filtered before it is processed by the microcontroller and transmitted to the smartphone. The following schematic was built is based of the the datasheet for CUI CMC-6022-37T.

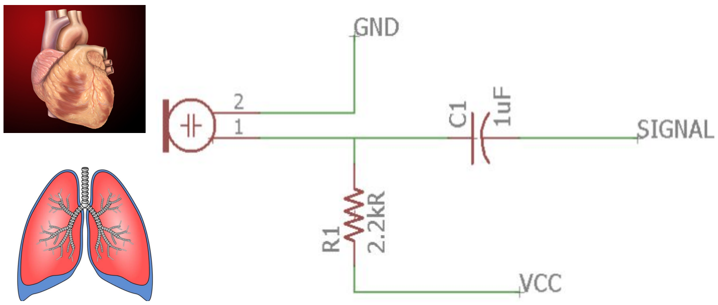

Figure 3: Microphone Unit Schematic

Requirements	Verification
• Have a Frequency response in the range 20 Hz - 20 kHz • Operate on 3 V +/- 0.1 V	• Produce audio and use the oscilloscope to plot the voltage response • Power the microphones with voltage in the range 2.9 V - 3.1 V

Power Unit

The Power unit will of a single power line which supplies 3 - 5 V in order to power the microcontroller, microphones, Bluetooth module and op-amps in the Signal Processing Unit. There will be a voltage regulator to ensure there are no voltage spikes which can damage the components of our system.

Requirements	Verification
• Generate 3 V +/- 0.1 V • Can operate at currents 0-200 mA • Batteries provide 3000 mAh of power	• Measure the output voltage from the voltage regulator and ensure that it stays within the 2.9 - 3.1 V range • Use a constant current circuit to draw 200 mA from the power supply and voltage regulator • Ensure that the batteries run for 15 hours at maximum current (200mA)

Signal Processing Unit

We have an independent Analog Signal processing unit for each microphone that amplifies the analog signal from the microphones and filters the noise. For the heart, the frequencies of the sounds we want to detect in lie in the range 20 - 150 Hz and for the lungs, the signals of interest are in the range 50 - 2500 Hz.

Requirements	Verification
• -3 dB Frequency Response below 25 Hz and above 300 Hz for filtering out heart sounds • -3 dB Frequency Response below 50 Hz and above 2500 Hz for filtering out lung sounds	• Use signal generator to generate signal at 25 Hz and below. Measure Frequency response to verify is -3 dB below. Repeat the process for signals 300 Hz and above. • Use signal generator to generate signal at 50 Hz and below. Measure Frequency response to verify it is -3 dB below. Repeat the process for signals 2500 Hz and above

Data Processing Unit

The microcontroller will process the filtered and amplified signal from the Signal Processing Unit, convert the data in to a .wav format and send it to the communication unit. The .wav file structure is as follows:

Positions	Sample Value	Description
1 - 4	"RIFF"	Marks the file as a riff file. Characters are each 1 byte long.
5 - 8	File size (integer)	Size of the overall file - 8 bytes, in bytes (32-bit integer). Typically, you'd fill this in after creation.
9 -12	"WAVE"	File Type Header. For our purposes, it always equals "WAVE".
13-16	"fmt "	Format chunk marker. Includes trailing null
17-20	16	Length of format data as listed above
21-22	1	Type of format (1 is PCM) - 2 byte integer
23-24	2	Number of Channels - 2 byte integer
25-28	44100	Sample Rate - 32 byte integer. Common values are 44100 (CD), 48000 (DAT). Sample Rate = Number of Samples per second, or Hertz.
29-32	176400	(Sample Rate * BitsPerSample * Channels) / 8.
33-34	4	(BitsPerSample * Channels) / 8.1 - 8 bit mono2 - 8 bit stereo/16 bit mono4 - 16 bit stereo
35-36	16	Bits per sample
37-40	"data"	"data" chunk header. Marks the beginning of the data section.
41-44	File size (data)	Size of the data section.
Sample values are given above for a 16-bit stereo source.		

Requirements	Verification
10 bit ADC with 60 ksps 10 Analog Input Lines for ADC .wav file conversion of the digital output from the ADC	- Generate a signal as per the Nyquist frequency requirement of greater than 60 Hz - Generate 10 different analog signals and read the digital output. Compare the digital output to the original signal - Run the output of the ADC through test code for data conversion and ensure output format is .wav

Memory

The memory will store the patients data. The data stored will contain the heart and lung audio file of the patient as well as the time it was recorded. This unit is needed so that the doctor can access the patient's history at any given time. This unit will store several megabytes of data.

Communication

This unit will be the interface of our device to the outside world and will consist of a Low Power Bluetooth module. It will make sure that the patient's information is sent to the right people. Relatively speaking, this unit will not need much power. It will only need to be powered when information is being sent.

Requirements	Verification
Ability to communicate through UART or SPI	Check Datasheet to confirm the communication protocol required for the Bluetooth chip

Sound File Receiving Unit

The receiving unit will consist of a smartphone through which the user will be able to access the sound files generated from our system using an Android application. These sound files can then be sent to a doctor for an accurate diagnosis of the patient's condition.

Risk Analysis

The biggest risk in this project is incorrectly filtering the biological signals and sending sound files to the smartphone via the Bluetooth communication module. Heart and lung sound signals are really small and we have to filter noise produced by other organs. We also have to isolate the heart and lung sounds from each other. Moreover, we need to ensure that our sound files are able to recreate the stethoscope experience for the doctor, so that they can accurately diagnose the problem. We also need to ensure that we are able to transmit our audio file via Bluetooth and that the module can be easily interfaced with our microcontroller.

Ethics and Safety

There are several aspects of the project that can pose a safety hazard to the user. The Power Unit consists of batteries providing a total of 3 V to our system and it can easily overheat causing discomfort to the user and correlates to the IEEE Code of Ethics #9.
Another possible hazard is water which can short the components on the circuit board and even harm the user which again correlates with the IEEE Code of Ethics #9. We need to ensure that the user is not sweating while wearing this shirt and it is not worn for prolonged periods of time.
The material of our shirt is another safety concern as certain materials can cause allergic reactions in some people. We are using a shirt made of 100% cotton for this project and are going to ensure that the volunteers testing this suit do not have such allergies. We will make sure that the user is aware of the materials used to build the suit following IEEE Code of Ethics #3.

A crucial factor in determining the success of the suit is whether doctors are able to detect the relevant sounds from the sound files generated by the system. Therefore, we need to make sure that we work closely with a doctor and a patient to make our device better in accordance with IEEE Code of Ethics #7.

Since this shirt is a medical device, we need to make sure Food and Drug Authority (FDA) medical device regulations are satisfied and the need for human participants in this project requires us to follow the Institutional Review Board (IRB) guidelines.

References

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