Wireless Auscultation Device for Continuous Monitoring of Lung and Heart Sounds

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As a group we found that a need exists for the design of a wireless auscultation device for continuous monitoring of heart and lung sounds. Our goal is to develop biomedical technologies that will enhance the lives of people in the developed world and we want to promote healthy living by improving the current methods of auscultation. To do this, we are creating a device that can be used by both patients and their physicians in a hands free manner. Our device will be easy to use, low cost, and comfortable, so that it can be used for a reasonable amount of time during continuous monitoring. In order to create this device we will be using a battery, an audio pick up source, an amplification and filtering unit, an analog to digital converter, and a Bluetooth transmitter.

Auscultation is the act of listening to internal body sounds as a part of making a medical diagnosis. Every organ of the body is unique and each has a specific sound profile that can be used to determine healthy functionality. When these sounds change they can uncover clues about what is happening in that part of the body. Observation and palpation of the body are not always enough and this is why auscultation has become a reliable diagnostic source for so many clinicians around the world. A lot of correct diagnoses come with experience and it takes time to understand the specific sound profiles that separate healthy from unhealthy. There are many things to listen for and not every clinician knows them all. However, despite this fact, a full auscultation exam should assess 4 different things -- blood pressure, sounds of the heart, sounds of the lungs, and sounds of the bowels.

Specifically for our project, we chose to focus on heart and lung sounds since so many medical issues arise from these organs of the body. First, when listening to the heart, a clinician
will listen for the rate, type, and rhythm of heart sound, as well as any sounds that should not be there, such as gallops, murmurs or clicks. For heart sounds, clinicians listen to four primary areas: left and right of the sternum at the level of the 2nd rib, left of the sternum at the 4th rib, and on the left nipple line at the level of the 5th rib. These are the key locations of the valves of the heart and auscultation at each location will provide enough information to determine a healthy or unhealthy heart [1]. Second, when listening to the lungs, a clinician will identify the rate, rhythm and quality of breathing, any obstructions of the airways, and any rubs that indicate inflammation. For lung sounds, clinicians listen to six paired areas on the chest and seven paired areas on the back. Auscultation occurs from top to bottom in this procedure and the left and right sides of each pair are compared simultaneously in order to make any differences between sides more apparent [2].

Currently, the methods of treatment are not highly differentiated. The most common devices used for treatment include using mechanical and electrical stethoscopes. The mechanical stethoscopes are the ones that we see in most healthcare applications and are the most basic form of device used to listen to the sounds of the body. These devices, both mechanical and electrical, are used in the same manner, but their benefits differ in each type. Electrical stethoscopes give the ability to filter certain sounds, amplify signals of particular interest, as well as some offer the ability to reduce outside noise. Mechanical stethoscopes, on the other hand, provide the option of being lightweight and free from bulk, as well as being cheap and easily replaced [3]. They are currently the golden standard for auscultation. However, each of these methods requires a doctor to be tethered to the patient and sounds can only be monitored intermittently. Our device would address this issue and would allow for continuous monitoring of heart and lung sounds.
The current auscultation market includes acoustic stethoscopes which cost anywhere from $5 to $160 and electronic stethoscopes which range anywhere from $150 to $1000 [4]. This is important to note because price is a large factor when choosing an auscultation method. Our device needs to compete with electronic stethoscope prices and it needs to prove that the sound quality is just as good. However, the market for our device will be much smaller than the current stethoscope market. Continuous monitoring is unique and because of this we need to address patients who might use this at-home as well as doctors for intensive care purposes.

Stakeholders who would be affected by this need are patients, hospitals and other healthcare providers, medical manufacturers, and venture capitalists. Patients would be able to monitor their body sounds at home and physicians would be able to use our device to monitor sounds from the comfort of their office. Finally, medical manufacturers and venture capitalists are directly affected by this need because they can invest in the product and increase their revenue. This need would be greatly supported.

After conducting research we have found that there are not any devices presently being used to continuously monitor a patient’s heart and lung sounds. This in itself makes our device novel. Although there are research projects being done and devices that have been created, none of these devices are readily available for a physician at this moment. Being able to monitor a patient that is on a medication is one way that our device can be useful. Just as patients are monitored through vital signs as they receive new medication for the first time in a hospital setting, our device could do this using auscultation. Additionally, continuous monitoring of body sounds could provide a non-invasive and inexpensive means of diagnosing accurately and promptly in many clinical conditions, such as misplaced intubation tubes, asthma, pulmonary
edema, and detecting critical or even life-threatening situations such as airway obstruction, or collapse of lungs.

For our design concept we will be creating a wireless and hands free auscultation device that will continuously monitor the heart and lung sounds. Our design consists of 5 key components, which include an auscultation pick up, amplification and filtering of the analog signal, analog to digital conversion, Bluetooth system, and batteries. Figure 1 represents our block diagram of the components.

![Auscultation Block Diagram](image)

Figure 1: Block Diagram of Wireless Stethoscope

For the pick-up, we are looking at a microphone that will connect to our device with two leads. When choosing the appropriate microphone, we are looking at the frequency at which the microphone picks up sound, the operating supply voltage, and the size. Figure 2 represents a potential microphone that could be used.
When considering the sound pick-up, as well as the device altogether, we also need to isolate other noises that the microphone could detect. To help with that, we are looking into various sound isolating materials. For instance, polyvinyl chloride (PVC) could be a potential option because it is a sound isolating material that is already used for the tubing of current mechanical stethoscopes. Additionally, because our design must keep the device on the patient’s body, we expect to use a lightweight adhesive patch. To choose the most appropriate patch, we need to make sure that it creates minimum to no skin irritation and that it can adhere to the patient for a longer period of time. Our device should be able to last throughout the average time period for a typical hospital visit. Figure 3 is a prototype of a device attached to an adhesive patch that could potentially be used in our design.
Next, the analog signal will be processed. In this stage of the design we will need to consider two things; first, the amount of gain needed for our signal and two, the filter type that we are using. The gain will be determined based on the op-amp we choose to amplify the sound and the filter design is based on the frequency of the heart and lungs. Heart sounds range from 20-650 Hz and lung sounds range from 70-2000 Hz and because of this range we expect to use a low pass filter [7]. Following this, the analog signal will be converted into a digital signal in order for us to transmit data through a Bluetooth system. We are using a microcontroller and our specification for this component will be the operating supply voltage and the size. A couple of similar components are shown in Figures 4 and 5, which represent an op-amp and a microcontroller, respectively.

![Op-amp](image1.png) ![Microcontroller](image2.png)

**Figure 4: Op-amp [8]**

**Figure 5: Microcontroller [9]**

After conversion of the signal from analog to digital, the Bluetooth system will be used in order to wirelessly transmit the data to a monitoring device such as a phone or laptop, which are devices that are already Bluetooth capable. There will be a Bluetooth transmitter in our device and a Bluetooth receiver on the receiving end. Our specifications for the Bluetooth system will be the amount of power it needs, the range at which it can transmit, the cost of the unit, and the size. Figure 6: represents a Bluetooth module we are interested in.
Finally, our whole device will be powered by a battery or multiple batteries. In order to choose the best power source we are looking at current (mAh) of the battery, the operating supply voltage, and the size. Figure 7 represents a potential battery what will power our device, similar to that of a watch battery.

To end of discussion of our design it is important to note that we will not be creating anything on the receiving end of our wireless auscultation device. Once the data is transmitted to the Bluetooth receiver, the monitoring device, such as a laptop or phone, will collect the data from the Bluetooth receiver and an application or program that is already available to people with these technologies will analyze and record the data.
Figure 8 represents the timeline for the Spring Semester. Over winter break, between Dec. 20th, 2014 and Jan. 11th, 2015 we will become experts in the various components of our device. Danielle will become an expert on the Bluetooth and battery aspect of the project, Matt will become an expert on the sound pick up and the isolation of sound and Stephen will become an expert on the analog to digital converter and the signal processing. This means we will learn how the components work, which materials will work best based on our design criteria, and which materials will work best together. Throughout the project though we will be working on everything together and getting everyone knowledgeable on each aspect of the design and components. We will be comparing various specifications such as cost, power used to operate, range (either distance or frequency), operating voltage, and size. Over winter break, we will also begin some preliminary development of the wired prototype. We will do this by wiring all of the circuitry on a breadboard and then connecting a microphone and speaker on either end. We will also do some preliminary testing. Starting the spring semester, we will compact the wired prototype, finalize the design and conduct more in depth testing. We will compare the sound pick-up of our prototype to a mechanical stethoscope. At the end of January we will finalize and test our wired prototype. On February 3rd, 2015, we will present our project to Legends Entrepreneurial Student Awards (LESA) to receive funding in order to build our wireless
prototype. However, regardless of whether or not we receive funding, we will begin creating our wireless prototype, which will concentrate on converting the analog signal into digital. We will use a microprocessor and a Bluetooth system in order to wirelessly transmit the data to a monitoring device and expect finish an initial wireless prototype by mid-March. After this, we will have about a month to test and finalize our wireless device. Finally, we will prepare for our presentations. We will show our project at the poster presentation on April 23rd, 2015 and our final presentation on May 1st, 2015.

<table>
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<th>Component</th>
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<tr>
<td>Microphone circuit development</td>
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<tr>
<td>Sound absorbing material</td>
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<td>Batteries</td>
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<tr>
<td>Electrical components (Passive and Active)</td>
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<td>Bluetooth System</td>
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<td>PCB</td>
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Figure 9: Project Budget
Figure 9 represents our project budget. We will spend $10 in order to purchase microphones for testing and development. Some microphones might also be donated to us from Professor Cook. We will spend no more than $20 in order to purchase sound absorbing material. We will spend up to $25 for batteries, and some of these may also be donated to us from Professor Cook. We will spend up to $150 for electrical components, both passive and active, which includes resistors, capacitors, and power sources. Some of these could also be provided to us from the university. We will spend up to $100 for a Bluetooth system and $100 for a Printed Circuit Board (PCB). Overall, we expect our total budget to be approximately $405. We are hoping to receive funding the LESA Foundation, but if we do not receive any funding, we will fund the project ourselves.
References


