Wearable Auscultation Device Design
Giyilebilir Oskültasyon Cihazı Tasarımı

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***Abstract*—Auscultation is a treatment method frequently used by physicians in terms of giving general information about the body. By listening to the sounds of breathing, the physician can have a general knowledge of the patient's body. In addition, respiratory distress occurs in many diseases such as COPD and asthma. The development of biomedical device technology makes it faster and easier to diagnose and treat. In this study, an electronic equipment has been prepared for the auscultation process. It has 4 channels in the hardware, and two of the channels listen to the heart. Of the remaining 2 channels, one performs listening to the left and the other the right lung. A filter is designed for the heart, which decays between 20-500 Hz. Since breathing sounds can be heard at a wider frequency, a filter has been prepared that passes between 100-1000 Hz.**

Keywords*—biomedical device design; auscultation; wearable technology

***Özetçe*—Oskültasyon, vücut hakkında genel bilgi verebilmesi açısından hekimler tarafından sıkılıkla kullanılan bir tedavi yöntemidir. Solunum seslerinin dinlenmesi ile hekim hasta vücudu hakkında genel bir bilgiye sahip olabilmektedir. Ayrıca solunum rahatsızlığı KOAH, astım gibi birçok hastalıkta ortaya çıkmaktadır. Biyomedikal cihaz teknolojisinin gelişmesi, yapılacak teşhis ve tedavileri daha hızlı ve kolay hale getirmektedir. Bu çalışmada oskültasyon işlemi için elektronik bir donanım hazırlanmıştır. Donanımda 4 kanallı olup kanallardan ikisi kalbi dinlemektedir. Kalan 2 kanaldan biri sol diğeri sağ akciğeri dinleme işlemini gerçekleştirmektedir. Kalp için 20-500 Hz arasını geçiren bir filtre tasarlanmıştır. Solunum sesleri daha geniş bir frekansta duyulabildiği için 100-1000 Hz arasını geçiren filtre hazırlanmıştır.**

Anahtar Kelimeler*—biyomedikal cihaz tasarımı; oskültasyon; giyilebilir teknoloji

I. Introduction

Biomedical device technologies have made significant contributions to the development of diagnosis and treatment processes. Rapid diagnosis of the disease and initiation of rapid treatment becomes even more possible with the development of technology. In terms of health, the need for technology is increasing day by day.

Auscultation is listening to the sounds of your heart, lungs, and belly (abdomen) as a medical definition. The auscultation method is performed with a stethoscope. A stethoscope is a tool that all doctors use. The word stethoscope comes from the Greek words stethos meaning chest and skopein meaning to explore. Rene Theophile Hyacinthe Laennec invented the stethoscope in 1816. After 1956, cardiologists such as Litmann and Leatham made arrangements to be used today [1].

Auscultation is performed from 3 regions: heart, abdomen, and lung. Heart sounds are produced by the movement of blood in the cardiovascular system and the opening and closing of the heart valves. With the help of the microphone, the sounds of systolic, diastolic, and heart murmurs can be heard. A normal heart produces a first heart sound (S1) and a second heart sound (S2). Abnormal heart sounds are important parameters that provide information about the disease status of the heart. The appearance of sounds different from the normal sounds S1 and S2 in the heart means that there is a problem in the heart. All respiratory sounds heard or detected on the chest wall or inside the chest, breath sounds detected in this position and incidental sounds constitute lung sounds [2]. The sounds originating from breathing detected on the chest wall of healthy people are called normal lung sounds. These sounds are characterized by a quiet, low-frequency sound during inhalation and are almost inaudible during exhalation. Additional sounds are sounds that occur after some pathophysiological conditions that should not normally occur. Additional sounds are classified as continuous additional sounds and intermittent additional sounds. Continuous sounds consist of Roncus and Wheeze, while intermittent sounds consist of fine crackling and coarse crackling. The abdomen is the region where abdominal and bowel sounds can be heard. By auscultation of the sounds emanating from these organs, information about the patient's condition can be obtained. Although bowel sounds provide information about digestive processes, the authenticity of these sounds makes their interpretation difficult. Bowel sounds may appear at irregular intervals and may radiate from different abdominal regions. For this reason, it depends on the patient and requires long-term analysis [3].

One of the most basic diagnostic methods in the field of health is treatment with auscultation. The process of resting body sounds is called auscultation. There are 3 auscultation zones - cardiac, pulmonary and belly (abdomen). This method provides general information about the region that is being listened to by the physician. A stethoscope is used for auscultation. It is one of the most widely used medical instruments by doctors. Rene Theophile Hyacinthe Laënnec invented the stethoscope in 1816. At first, listening was done with one ear.

With the change of materials and design used over time, it has become the classic stethoscope today. The advancement of technology has also enabled the development of stethoscopes. Electronic stethoscopes perform the process of filtering and amplifying the sound they receive. This allows doctors to better perceive low-frequency sounds. The smart stethoscopes used today perform listening and recording operations.

There are many different studies in this field [4]–[6]. Different electronic stethoscope designs have been made in the past periods. Selek et al. developed an electronic stethoscope and aimed to observe the audio signals graphically. Amplification process was implemented by the MAX 9814 microphone amplifier. After amplification, the signals could be filtered to remove unwanted frequencies from the system. Arduino Mega was used as a microcontroller. As a result of the study, the S1 and S2 signals of the heart sounds were displayed [6]. Malik and his colleagues used a MEMS sensor to pick up sounds in the system design. In addition, the signal was sampled and digitized using an Arduino Due. The data obtained were analyzed in Matlab. Fourier transform techniques have been adopted to provide time and frequency analysis of the data. LM741 and fourth-order bandpass filter was used in the circuit filter. The highest frequency of interest was determined to be 150 Hz, and therefore, taking into account Nyquist's theorem, 500 Hz was chosen as the sampling frequency, which is equivalent to a sampling time of 2 ms [7]. On the contrary, Altan et al. preferred using Hilbert-Huang Transform to find out features from lung sound [8].

Patil and Shastra used LM741 and LM386 opamps in their study. The op-amp LM741 was used in the design of the preamplifier circuit. The sound received in the design is increased by 20 times. The output of the preamplifier is fed to an active low-pass filter with a cutoff of 100 Hz and 1000 Hz. The capacitor value is selected and the frequency is selected. The filter has a gain of 1.6. The output signal from the filter is processed by the power amplifier to provide the necessary power to drive the headphones for further amplification. The LM386 circuit is an audio amplifier designed for use in low-voltage consumer applications that provides both voltage and current gain for signals. The analog signal was transferred to digital as 12-bit using the PIC18f2423 microcontroller [9].

N. Jatupaiboon and his colleagues used 2 microphones in their design. Microphone 1, inserted into the tube of the conventional stethoscope, is inserted into the heart canal to detect the sound of the heart. Microphone II is placed next to microphone I to detect external noise. Two preamplifiers are used to amplify the signal from each microphone before operation. Two anti-aliasing filters and a fifth-order low-order pass filter have been used to prevent anti-aliasing with a cutoff frequency of about 3700 Hz. The analog signal was converted to digital with a sampling frequency of 10 bits and 8000 [10]. Hadiyoso et al. designed their electronic stethoscope to obtain sounds in the heart, respiration, and other body parts in the range of 20-1000Hz. The components used for the design of an electronic Stethoscope are a membrane, condenser mic, pre-amplifier (gain 26 dB), wide bandpass filter, audio power amplifier (gain 2 dB) and jack phone [11].

II. Materials and Methods

The wearable device filters and amplifies the signals it receives from the body and transfers them to digital media. The signals are sent to the computer environment for analysis and display (Fig. 1).

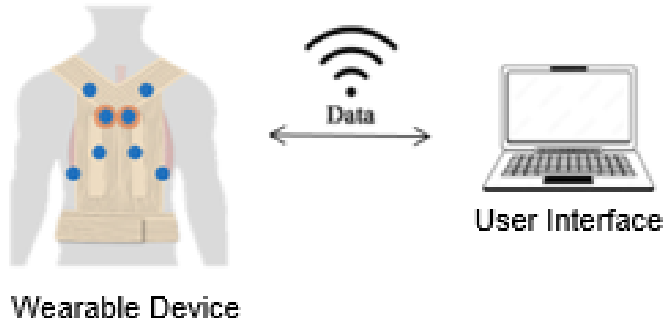

Figure 1: Circuit Diagram

A. Building the Hardware

When we look at the internal structure of the hardware, the signals obtained with the filtering and amplifying circuit are transferred to the sound card with the help of a jack. The sound card transfers the signal received from the jack to Raspberry via USB. Raspberry provides this signal to be transferred digitally (Fig. 2).

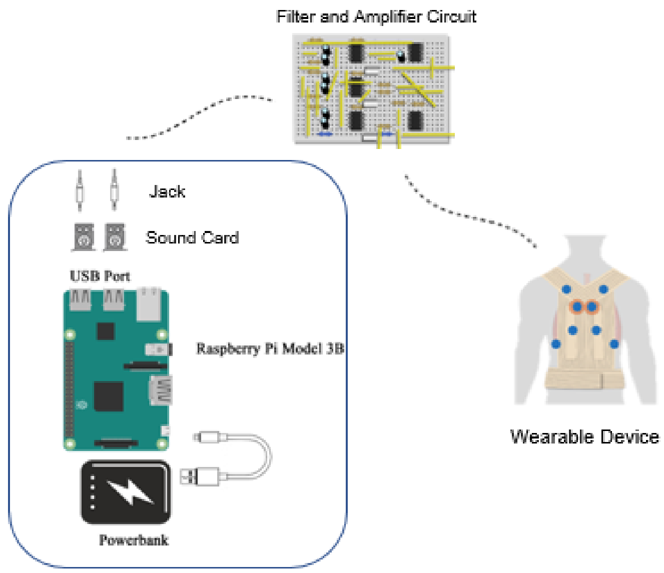

Figure 2: Internal Structure of the Wearable Device

An electret microphone is preferred for receiving audio signals due to its cheap cost and wide frequency range. In addition, First-order low-pass and first-order high-pass filters are used in the circuit to reduce high-frequency noises that will affect the analysis of breathing sounds. The components in Fig. 1 are determined according to the signal output voltage and frequency value. The electret microphone outputs about 100 mV from the C3 capacitor.

The signal received from the C3 output was passed through a high pass filter of 20 Hz for the heart and 100 Hz for the lung. A 10 uF capacitor and 1 Kohm resistor are used for the 20 Hz high-pass filter, while a 10 uF capacitor and 150 ohm resistor are used for the 100 Hz filter. The output voltage obtained from the filter is increased approximately 50 times with the AD620 amplifier. AD620's gain(G) is calculated using

$$G = \frac{49.4Kohm}{R} \quad (1)$$

R was chosen as 1 Kohm to increase the signal by a factor of about 50. R is R4 shown in Fig. 3. A low-pass filter of 500 Hz for the heart and 1000 Hz for the lungs was applied to the signal obtained from the opamp output. While a 22 nF capacitor and 10 Kohm resistor were used in the heart, a 22 nF capacitor and 7 Kohm resistor were used in the lungs.

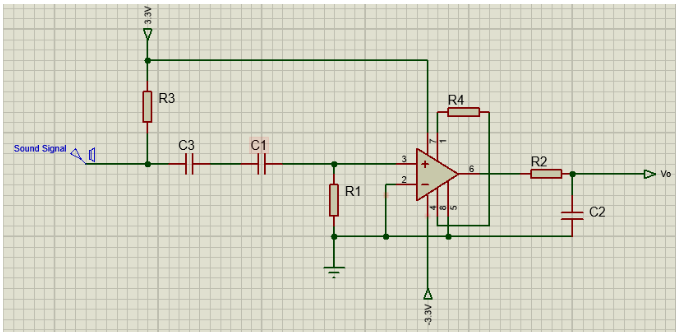

Figure 3: Circuit Diagram

4 channels in the hardware are seen shown in Fig. 4. Channels 1 and 2 are used for heart auscultation, while channels 3 and 4 are used for lungs. The negative voltage source provides -3.3 V voltage to the opamps in the hardware. The signals obtained from the channels are transmitted to the sound card and then to the Raspberry Pi. The sounds have a sampling frequency of 44100Hz. In addition, a 4th-order bandpass digital filter is applied to the received signals. This filter is between 20-500Hz for Heart and 100-1000Hz for Lung. Sounds are saved using Raspberry Pi.

4 points of the body listening locations were selected for the device. Due to the maximum 4-channel listening capacity of the hardware, 2 channels are placed on listening to the lungs and 2 channels are placed on listening to the heart. Listening points are shown in Fig. 5.

III. Results and Conclusion

When the literature is examined, it is seen that many biomedical equipments have been developed. These equipments to assist doctors are used for different purposes and procedures. There are many examples that show that technology facilities are used in a beneficial way in the field of health. Instead of single-channel electronic stethoscopes such as Litmann used today, a multi-channel system has been designed that allows physicians to analyze more easily. Thanks to the recording of the diagnoses made, an environment where data analysis can be made have been created. This study provides the opportunity to perform auscultation and send it to the physician without the patient going to the physician with the equipment created. Thus, the physician will ensure that the doctor is directed to the appropriate doctor for early treatment with remote treatment.

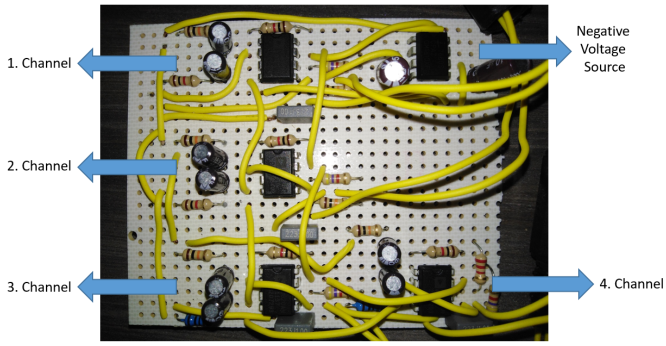

Figure 4: Display of Channels

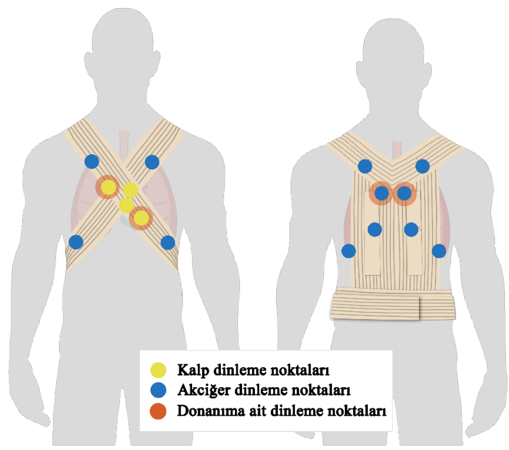

Figure 5: Device Listening Points

This study makes auscultation, which is the first examination procedure for most diseases, easier to be measured and evaluated. It is also designed in such a way that each person can do it himself. It provides an easy evaluation of this procedure, which is very difficult, especially for physicians with little experience and newly graduated, or sharing it with other physicians and obtaining opinions. This method makes the diagnosis more reliable. While this system enables the diagnosis of diseases with less experience, it also prevents the unnecessary use of expensive and time-consuming diagnostic methods. Since heart sounds are acquired as digital data, it will be a useful resource that is constantly growing and tagged which is another advantage of this study.

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