Department of

Electrical & Electronics Engineering

Abdullah Gül University

Electronic Stethoscope

EE2100 Signal Acquisition, Processing and Analysis Capsule (SAPA)

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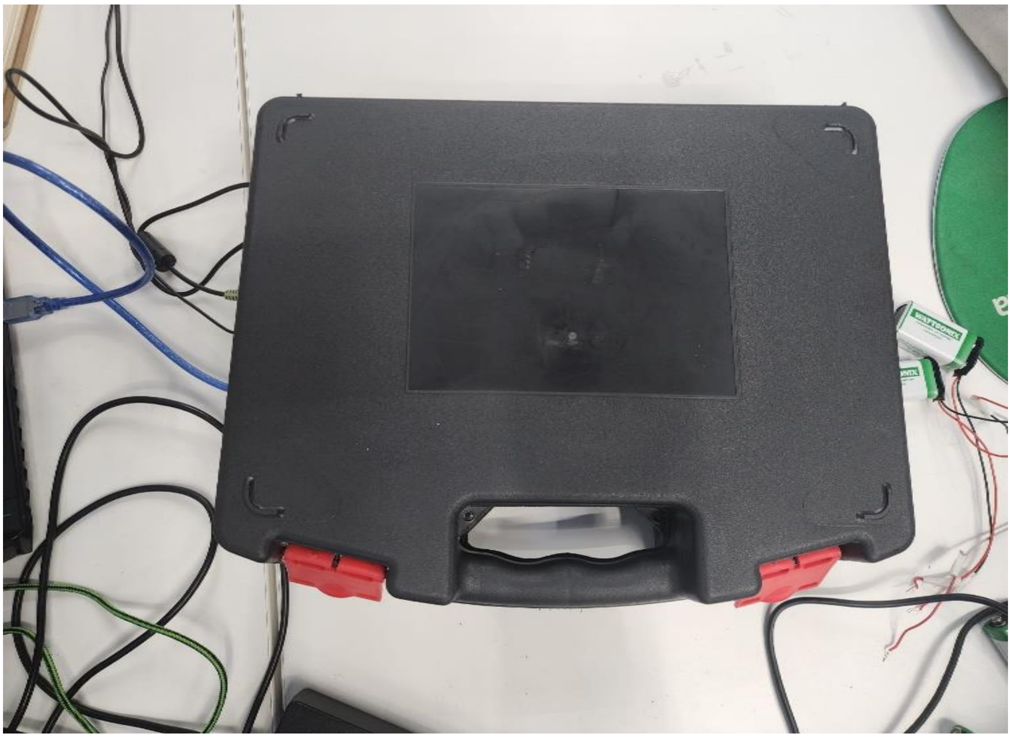

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Chapter 1
Introduction

OBJECTIVE

The purpose of this project is to construct an electronic stethoscope system which is used to acquire the sound from heart and lung system, to convert analog sound signal to a digital signal by using ARDUINO , to analyze the behaviour of respiration rate (breaths per minute) and heart rate (beats per minute), to observe the graph of signal which are heart and respiratory sound for determining abnormal situations by using MATLAB, to amplify and filtering the signals for providing the clear and distinct hearing of heart and breathing sounds and facilitating ease of use and accurate resolution for modern-day clinican.

BACKGROUND

The stethoscope has been utilized for many years to listen cardiac and breath sounds. In addition, the people who are interested in the field of health sciences have used these sounds as diagnosing the some ilnesses [1]. With the advancement of technology, traditional stethoscopes have started to be replaced by digital stethoscopes. Various diagnostic techniques, including lung ultrasound and phase-contrast X-Ray, have been employed to study lung fluid clearance. Digital stethoscopes, cost-effective and user-friendly devices, offer a potential tool for assessing breath sound characteristics [2]. On the other hand, Digital stethoscopes, by recording and processing heart sounds with high precision, provide doctors with the opportunity for a more detailed analysis. This technology becomes a crucial tool for the early diagnosis of diseases by detecting even subtle changes in heart sounds. Doctors apply more personalized and effective treatment methods to their patients using this detailed information [3]. AThe integration of digital stethoscopes into healthcare represents a significant advancement, offering cost-effective tools for assessing breath sound characteristics and enabling detailed analysis of heart sounds. This technology proves crucial for early disease diagnosis, facilitating doctors in applying more personalized and effective treatment methods based on precise information. As a result, the integration of digital stethoscopes into healthcare represents a significant advancement, offering cost-effective tools for assessing breath sound characteristics and enabling detailed analysis of heart sounds. This technology proves crucial for early disease diagnosis, facilitating doctors in applying more personalized and effective treatment methods based on precise information.

Chapter 2

SIMULATION PROCEDURES

i.

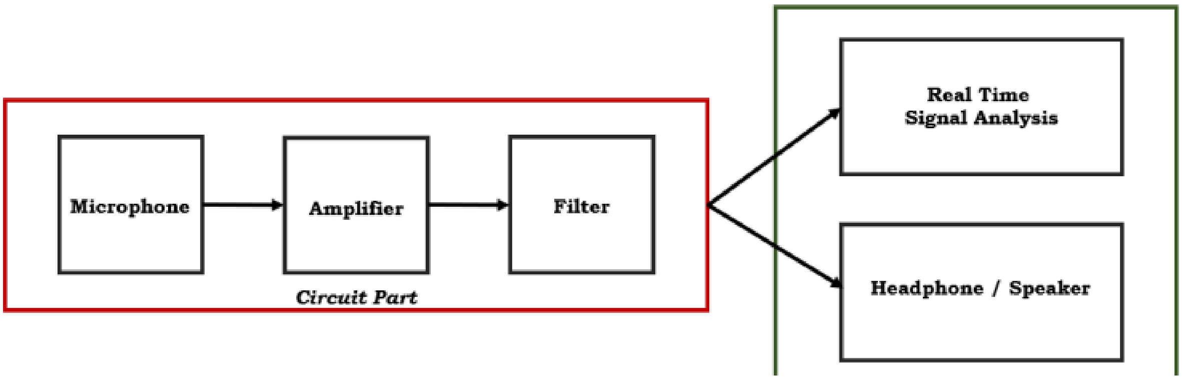


Figure 1. Project flow chart

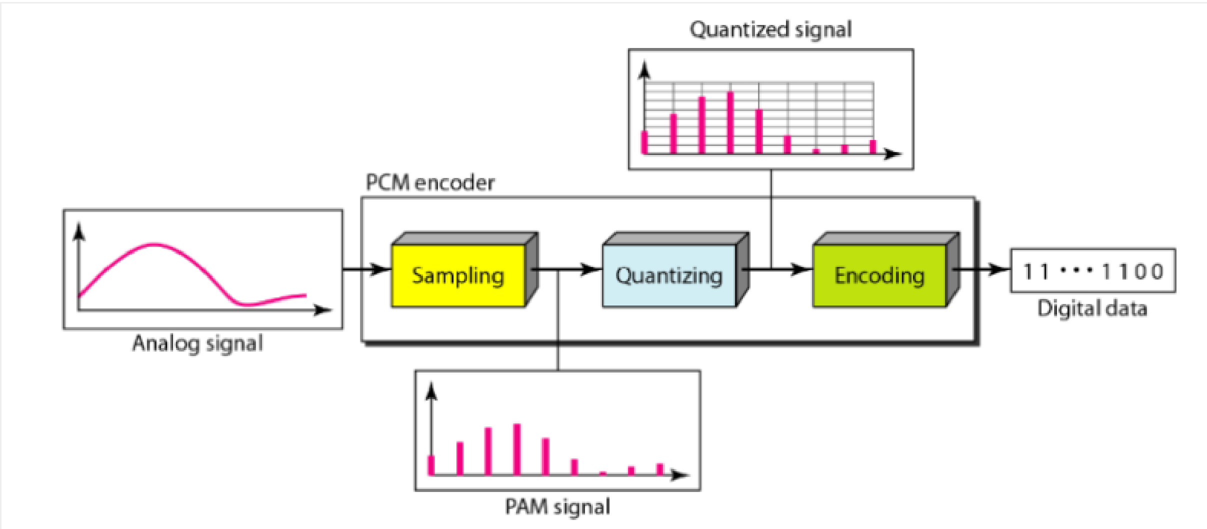


Figure 2. Process of analog to digital[4]

SHEMATIC CIRCUIT OF HEART RATE

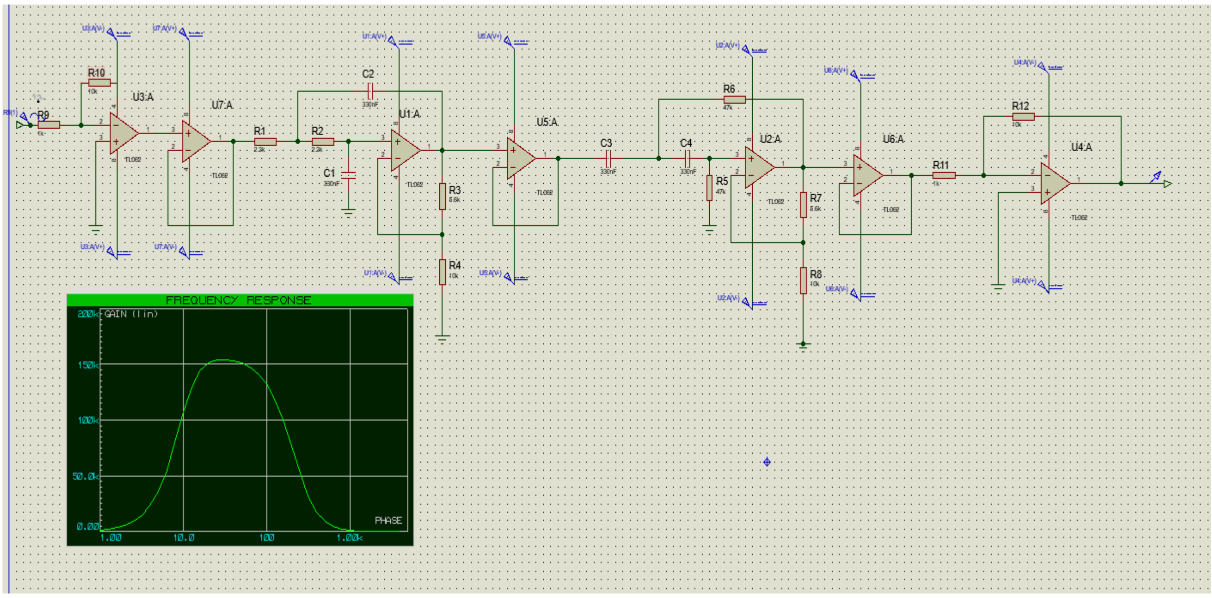


Figure 3. Frequency response of a heart sound circuit. (20*Hz*-200*Hz*)

SHEMATIC CIRCUIT OF RESPIRATORY RATE

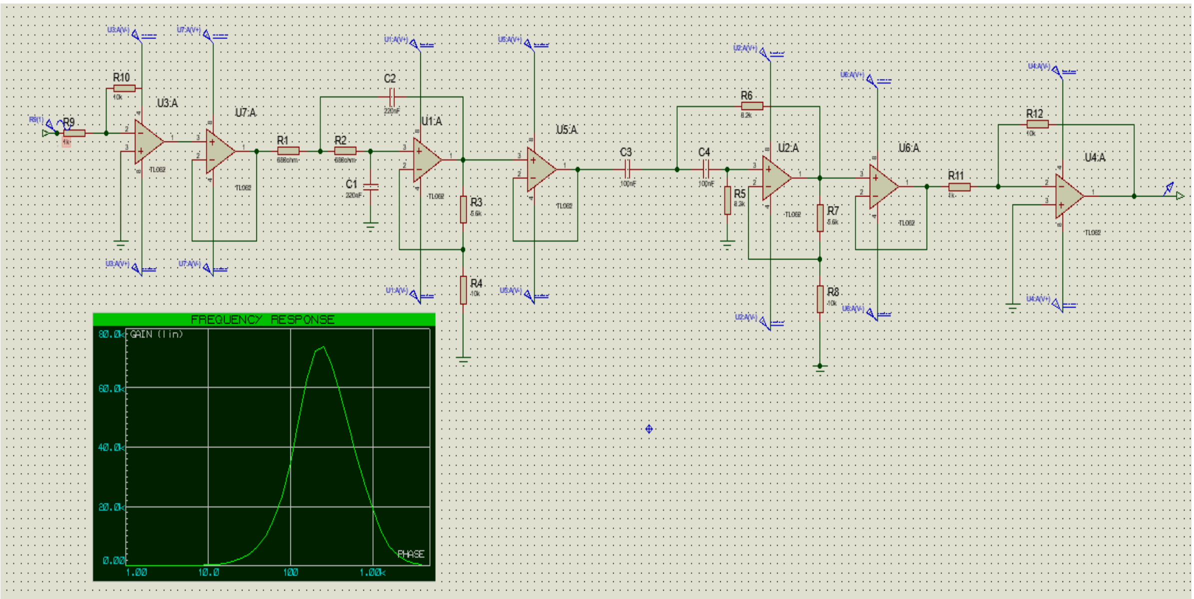


Figure 4. Frequency response of a Respiratory sound circuit. (300*Hz-1000Hz*)

MATLAB CODES

https://github.com/Ibrahimumutdoruk

Chapter 3

ANALYTICAL PROCEDURES

STEP-BY-STEP DESCRIPTION

(a)

In this project, 1k Ω (4), 10k Ω (10), 5.6k Ω (4), 680 Ω (2) , 2.2k Ω (2), 47k Ω (2), and 8.2k Ω (2) resistors, 330 nF (4), 220 nF(2) and 110 nF(2), 1000nF(1), 10µF(4), capacitors, buzzer(2), red LED(2), green LED(2), 9V cell (2), TL062 op-amp(14), 3.5mm Jak (2), jumper cables, breadboards (3), switches(2),black box, are used to built amplifier, Sallen-Key second order filter circuit, LED and microphone circuit. Protheus 8 Professional which is used to draw shematic of circuits, ARDUINO UNO R3 klon which is utilized to convert analog signal to digital and MATLAB which is used to observe frequency response, filtered and original signal of a circuits. Firstly, heart and respiration rate signals frequency range are determined which are 20*Hz*-200*Hz* [5], 300*Hz-1000Hz* [6]. Then, after this stage, a second-order Sallen-Key circuit diagram was created to generate low-pass, high-pass, and band-pass filters. Subsequently, to improve the clarity of the sound and observe the graph more precisely, the gain was increased by 110 times for heart sound and 347 times for respiratory sound. Buffer circuits were used at the input and output of each filter and amplifier circuit to prevent mutual interference. Following these processes, since Arduino analog pins read between 0-5V, 1V was added to the circuit output. The output of our circuit was then connected to the analog input of the Arduino. Afterward, communication between Arduino and MATLAB was initiated, and graphs of the filtered signal, raw signal, and FFT signal were observed. To monitor the graphs, an oscilloscope was used. In addition, for more convenient usage, a GUI was created using MATLAB App Designer.Finally, Real-Time plotting and listening provided.

(b)

i. This formula is used to find cut-off frequencies for Sallen-Key circuit and transfer function. (R=Resistance, C=Capacitance, R_f and R_i values to determine the gain, $f_c =$ Cut off frequency, ω=Angular frequency, H(ω)=Transfer Function, Y(ω)= Output, X(ω)=Input)

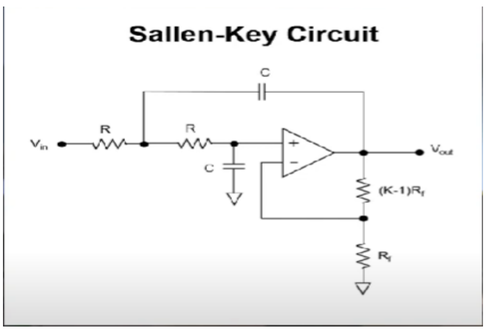
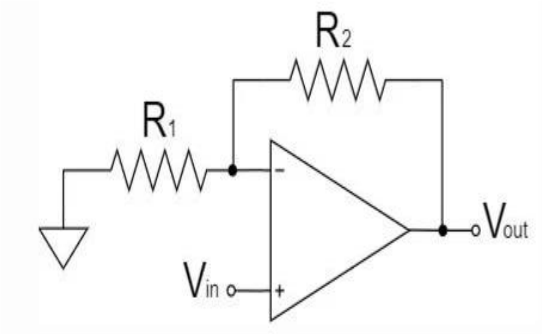


Figure 5. Shematic of Sallen - Key circuit [7]

$$f_c = \frac{1}{2\pi RC}$$

$$H(\omega) = \frac{Y(\omega)}{X(\omega)}$$

ii. This circuit design is used to determine amplifier circuit which non-inverting amplifier. Gain is calculated by using this formula (V_{in} = Input voltage, V_{out}= Output voltage, R_1, R_2 =Resistance of resistors)



$$V_{out} = (1 + \frac{R_2}{R_1})V_{in}$$

Figure 6. Shematic of Non-Inverting Amplifier [8]

Chapter 4

RESULTS AND DISCUSSION

CUT-OFF EQUATIONS

i. These Equations are used to determine the values of resistors values for both circuits that are second order highpass (R=Resistor values, C=Capacitor values).

$\frac{1}{2\pi RC} = 20\ Hz$ Capacitance is 330nF to find the resistor value for heartbeat.

R≅ 47k Ω

$\frac{1}{2\pi RC} = 300\ Hz$ Capacitance is 100nF to find the resistor value for respiratory.

R≅ 8.2k Ω

ii. These Equations are used to determine the values of resistors values for both circuits that are second order lowpass (R=Resistor values, C=Capacitor values).

$\frac{1}{2\pi RC} = 200\ Hz$ Capacitance is 330nF to find the resistor value for heartbeat.

R≅ 2.2k Ω

$\frac{1}{2\pi RC} = 1000\ Hz$ Capacitance is 220nF to find the resistor value for heartbeat.

R≅ 680 Ω

iii. V_{output}/V_{input} and Laplace transformation is used to know transfer function of second order Sallen-Key both circuits which are respiratory and heart. (H(s) = The transfer function, K = The gain of the filter, ω = The center frequency of the bandpass filter, Q =The quality factor of the filter, s= The Laplace variable.

$$H(s) = \frac{K\omega^2}{s^2+\frac{\omega}{Q}s+\omega^2}$$

The gain which is K is equal to 1.56 dB to make th system stable by using 10k and 5.6k resistors.

GAIN EQUATIONS

i. Gain is calculated which is “194” to listening the sound and showing the graph visually.

$K = \frac{10}{1} + 1 = 11$ dB for non-inverting amplifier.

There are 2 non-inverting amplifier and 2 Sallen-Key gain in the circuit. Therefore,

Total gain $=11 \times 11 \times 1.56 \times 1.56 = 194$ dB for the heart rate circuit.

ii. Respiratory circuit gain is calculated which is “74.76” to listening the sound and showing the graph visually for non-inverting amplifier.

$K = \frac{10}{2.2} + 1 = 5.45$ dB for non-inverting amplifier.

There are 2 non-inverting amplifier and 2 Sallen-Key gain in the circuit. Therefore,

Total gain $=5.45 \times 5.45 \times 1.56 \times 1.56 = 74.76$ dB for the respiratory rate circuit.

OSCILLOSCOPE RESULTS

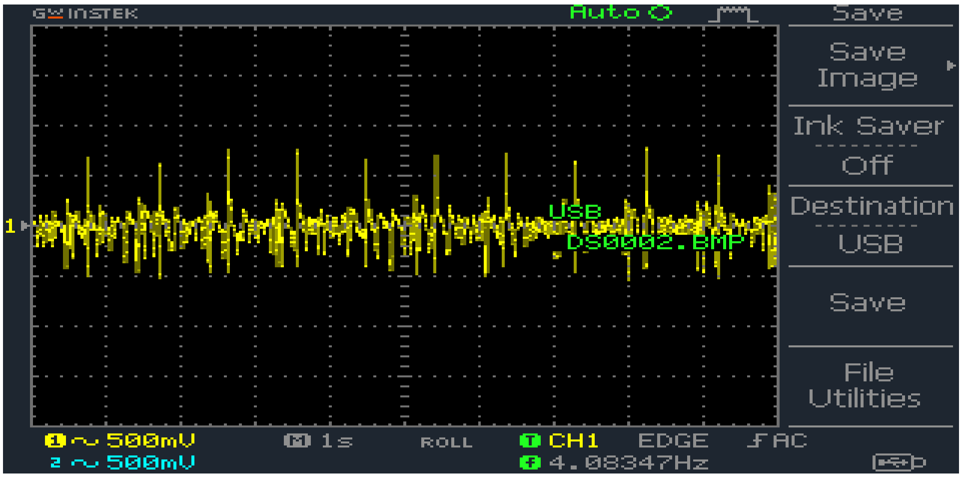


Figure 7. Showing the graph of heart rate circuit by using Oscilloscope.

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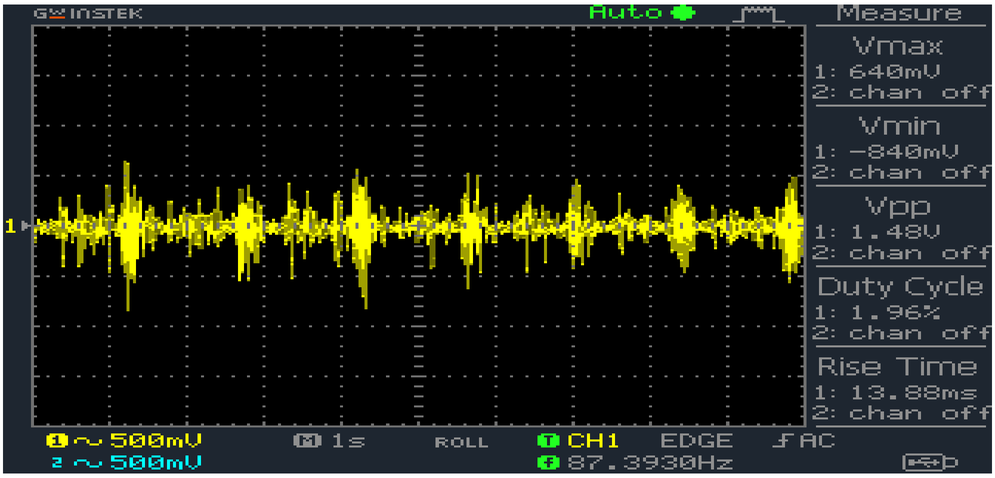

Figure 8. Showing the graph of Respiratory rate circuit by using Oscilloscope.

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MATLAB GRAPH RESULTS

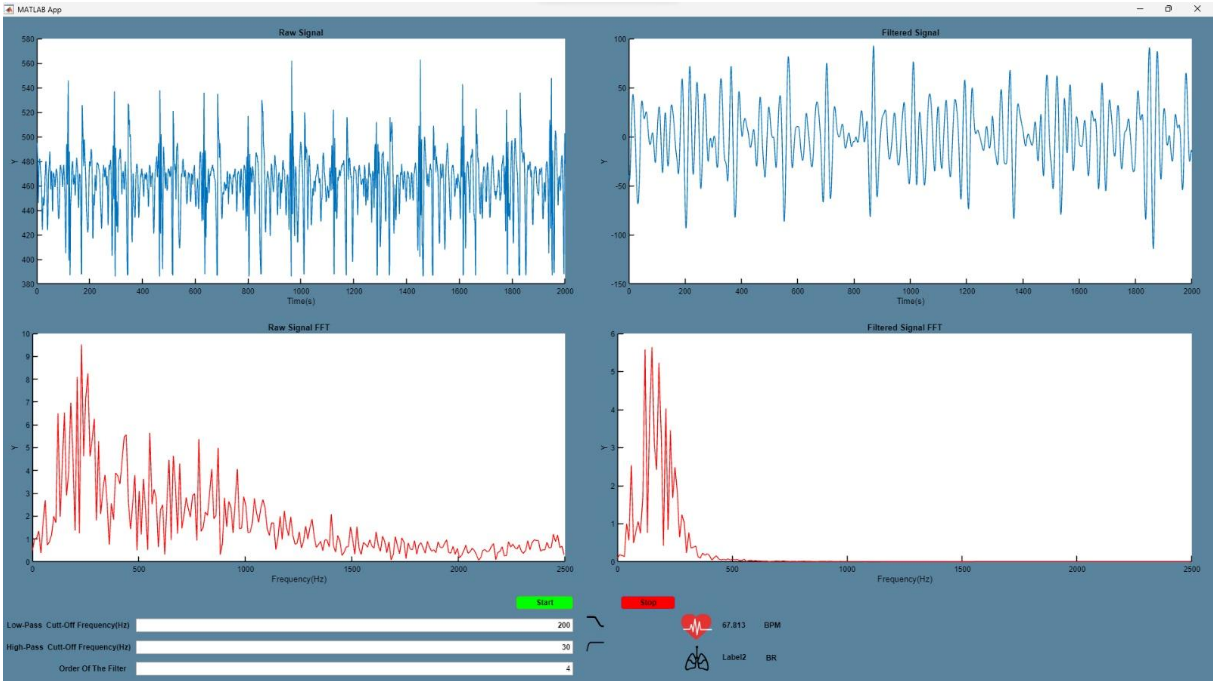

Figure 9. Observing the graph of Heart beat signals by using MATLAB GUI .

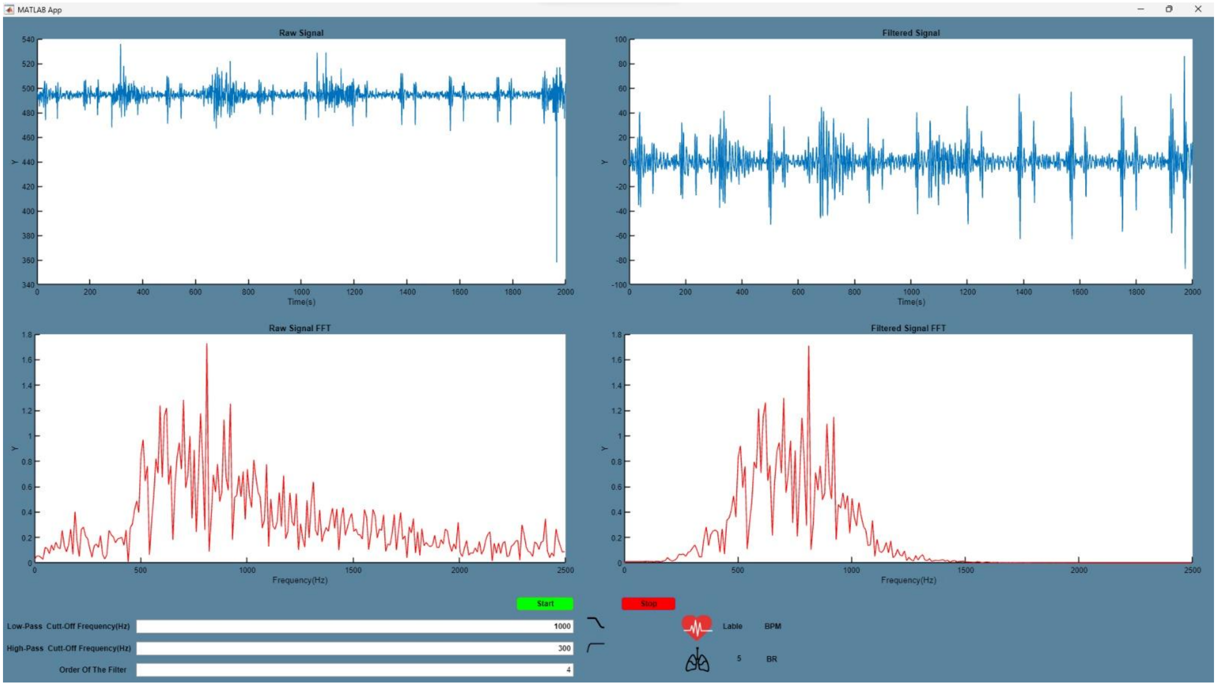

Figure 10. Monitoring the graph of Respiration rate signals by using MATLAB GUI .

DISCUSSION

In the project, Sallen-Key filter circuit, which is the work better according to experimental results, analog to digital conversion, Matlab app designer which is used to make GUI (graphical user interface), communication between Arduino and Matlab, obtaining the heart and respiratory sound signals were learned by preparing experimental and software setup. However, the results of the experiment were not reached with the expected and theoretical conclusion because some details are not included to calculations such as sensitivity of components which is related with manufacturing tolerances, leading to variations in their actual values in comparison to their specified and nominal values and the digital device which is arduino uno R3 clone having a limited bit processing range. If this experiment had been conducted in better components and using more precise devices and tools experimental results could have been obtained that would have matched or closer the theoretical results.

Chapter 5

CONCLUSION

The digital stethoscope, innovation in healthcare technology, offers a transformative solution to real-world challenges in respiratory and cardiac diagnostics. Through its advanced capabilities in displaying and listening to physiological signals, such as heart and respiratory sounds, it enhances clinical assessments with unprecedented precision and efficiency [9]. The project experiment demonstrates the device's seamless integration into medical practice, addressing the need for accurate and timely detection of cardiovascular and respiratory abnormalities. This technology not only streamlines diagnostic processes but also contributes to improved patient outcomes by facilitating early intervention and personalized treatment strategies, thereby exemplifying its significant impact on addressing critical healthcare concerns [10].

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