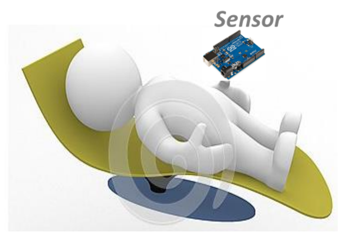
A Low Cost Bluetooth Powered Wearable Digital Stethoscope



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Introduction

With the use of electronic stethoscope which is commercially available nowadays, it is possible to amplify the acoustic signal as well as to store and replay. However, they are all taking a short period of cardiopulmonary sound and, at the same time, physicians are necessary to do diagnosis one by one. This makes the traditional and electronic stethoscope not efficient enough for the society nowadays. This paper proposed a wearable digital stethoscope which is possible to carry out real time monitoring over long distance giving better healthcare efficiency either for patient suffering from chronic diseases or the elders. It has further application for multiple points accessing, data storage and replay function for further diagnosis. This paper also provides idea on self-screening property for the newly designed stethoscope for auto disease preliminary assessment.

System Architecture

The device can be divided into the following parts; electret condenser microphone, pre-amplification module, low pass filtering module, microcontroller, memory card and the wireless transmission module.

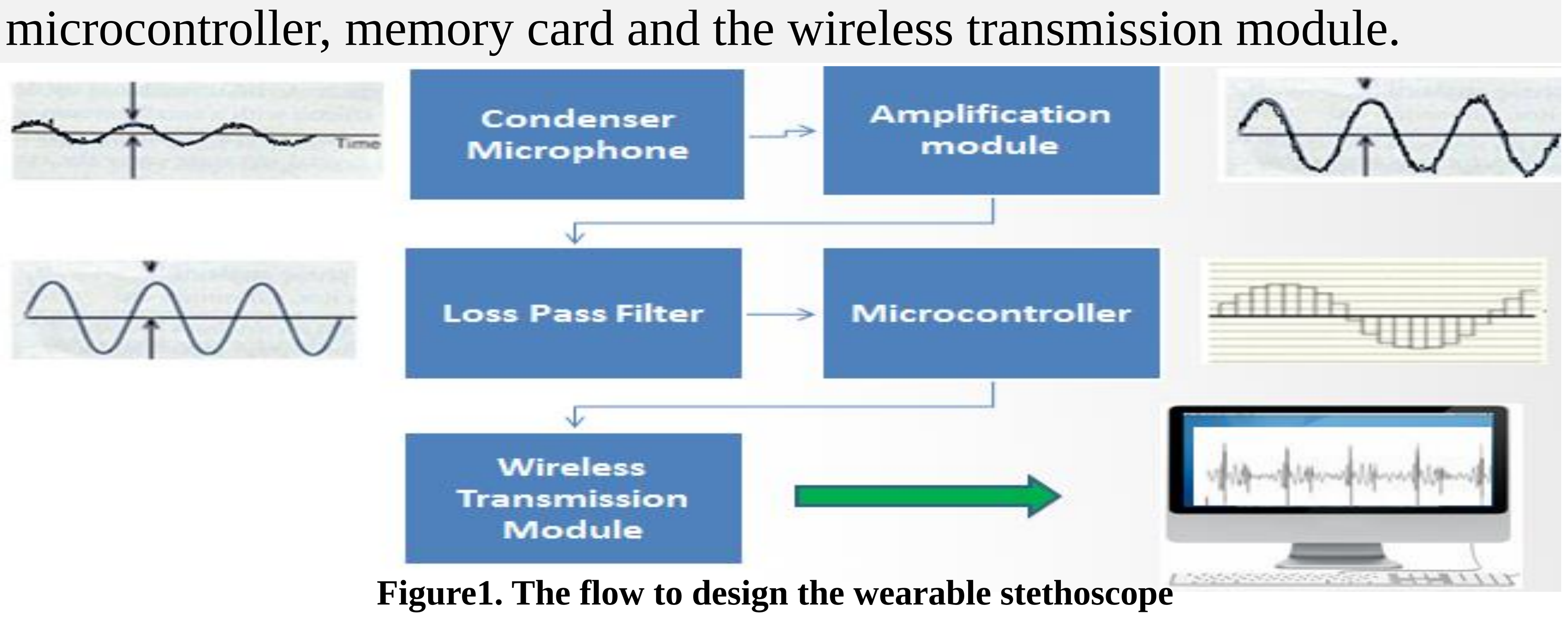

Figure1. The flow to design the wearable stethoscope

The acoustic signal can firstly be detected by condenser microphone (WM-61A). The signal will then be amplified by the amplification module (LM386). A second order active filter is then used to remove high frequency background noise. The analog to digital conversion is achieved by using Arduino Mega (MCU). The digital signal will be either transmitted wirelessly to personal computer for real time monitoring by using wireless transmission module (Bluetooth) or recoded in the SD memory card directly for further diagnosis purpose.

A. Electret Condenser Microphone

The condenser microphone used in the device is of great importance. Electret condenser microphone (WM-61A) has been used to capture the acoustic signal in this study, which gives high sensitivity (-35dB) as well as high S/N ratio (62dB)（Fig. 2)

B. Amplification Module

The acoustic signal comes out from the microphone is on the order of millivolts which is not significant enough to be converted to digital signal for further signal processing. Low voltage audio power amplifier LM386 is used to enlarge the gain for the signal. Gain setting is tuned to make the gain around 200.

Figure 2. The acoustic sensor with chest piece attached

Figure 3. The circuit board built for signal processing

C. Second Order Active Filter

It has been reported that the energy distribution for different frequency of normal heart sound ranges from 50 to 110. Statistical analysis also proposed that the frequency for abnormal heart sound lies below 1200Hz. The results conclude that the frequency above 1000Hz is not significant in determining whether users are suffering from heart disease or not.

D. DC-offset

Experimental results shows the acoustic signal at the stage after filtering swings around the middle line (-1.12V to +1.12V)（Fig.4). However, Arduino Mega (MCU board) can only accept analog input ranging from 0 to 5V. Any negative signal gives a possibility to damage the microcontroller board and the signal output from the microcontroller will end up clipping the bottom part. In order to reconstruct the signal without any loss of information, a dc-offset should be made in front of the analog input to microcontroller. This step can be simplified by just wiring the 5V output from the Arduino to the two 100K ohms in series, connecting another end of the resistor to the GND. In the middle of the resistors will simply give a half of 5V which is 2.5V pulling the negative range of signal to positive**.**

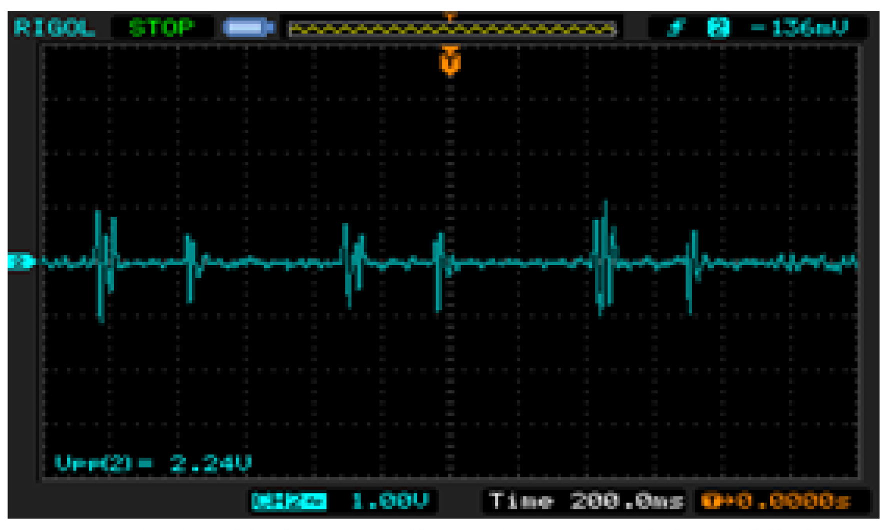

Figure 4. Acoustic signal before DC-offset swings around the middle line

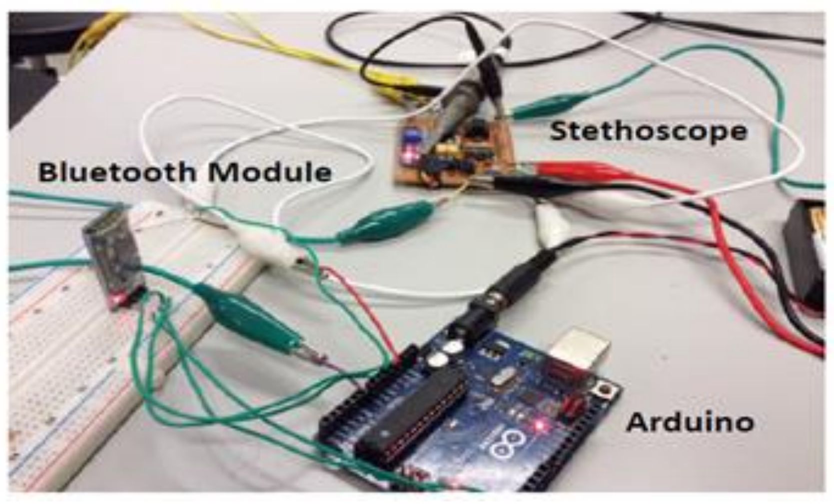

Figure 5. Experimental setup of the prototype

E. Arduino Mega

Arduino can achieve the analog digital conversion with its 10 bit A/D converter. The input signal will be given a number (0-1023) referring to the voltage applied, which means the signal can be divided into 1024 levels.

F. Bluetooth transmission module

HC-06 supports short-distance transmission as well as point to multipoint data transmission. To set up a Bluetooth connection between two devices, the first thing to consider is that whether the baud rate of the Bluetooth module matches the requirement. The setting is tuned to 9600 baud rate in this study Higher baud rate has higher transmission rate, but at the same time, there are drawbacks. They are either due to the higher error rate or connection failure.

Results and Discussion

Several functions can be achieved by using the **Wireless Acoustic Signal Transmission System** designed by LabVIEW, such as real time monitoring, data storage and replay function.

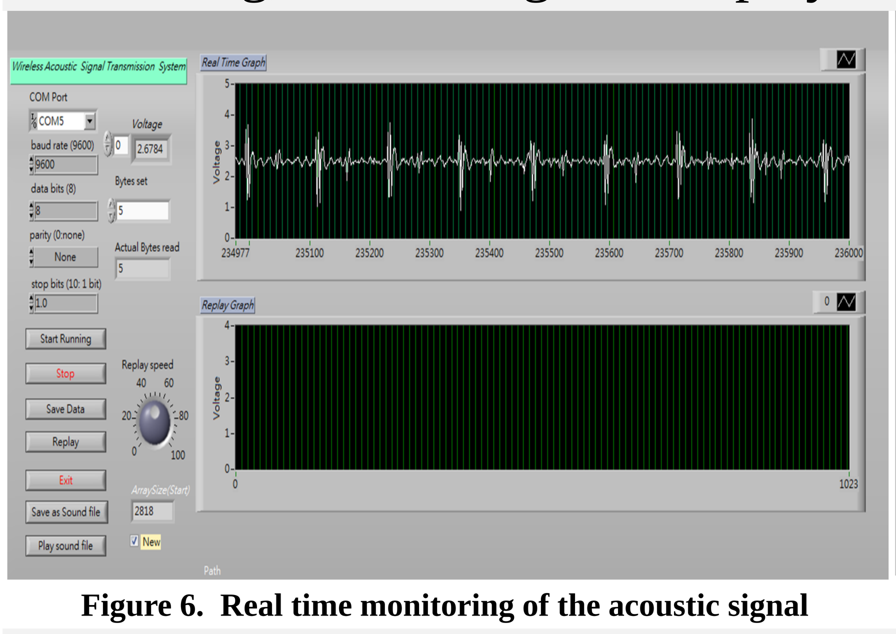

Figure 6. Real time monitoring of the acoustic signal

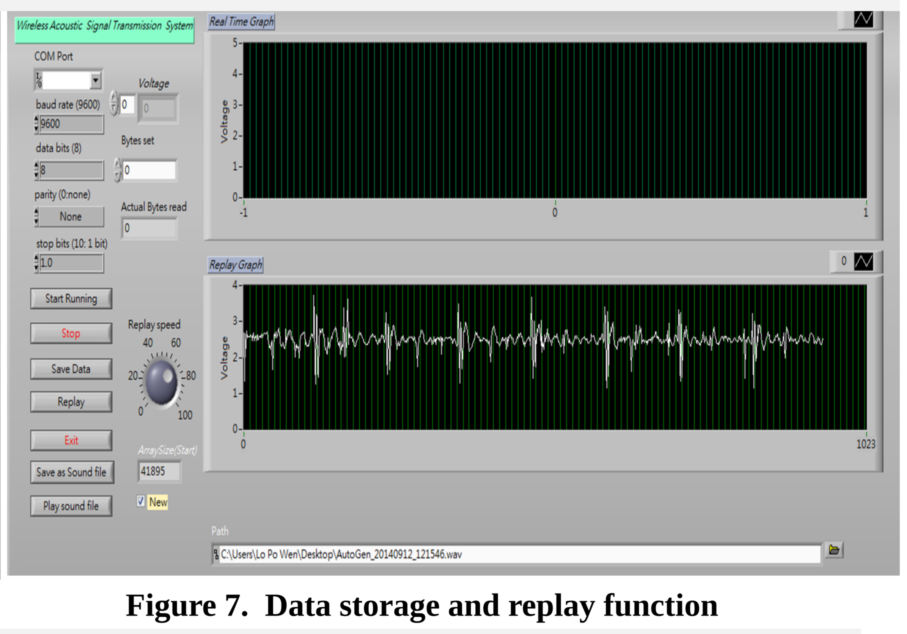

Figure 7. Data storage and replay function

National Instrument LabVIEW makes the Wi-Fi transmission with peripheral devices possible, which means signal transmission distance will not be limited by the coverage area of Bluetooth anymore. The following figure shows the result coming out using Wi-Fi transmission.

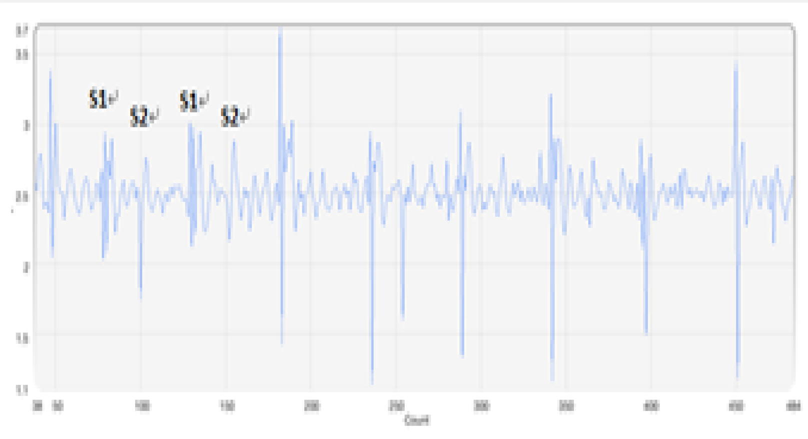

Figure 8. Waveform displayed on Ipad using Wi-Fi

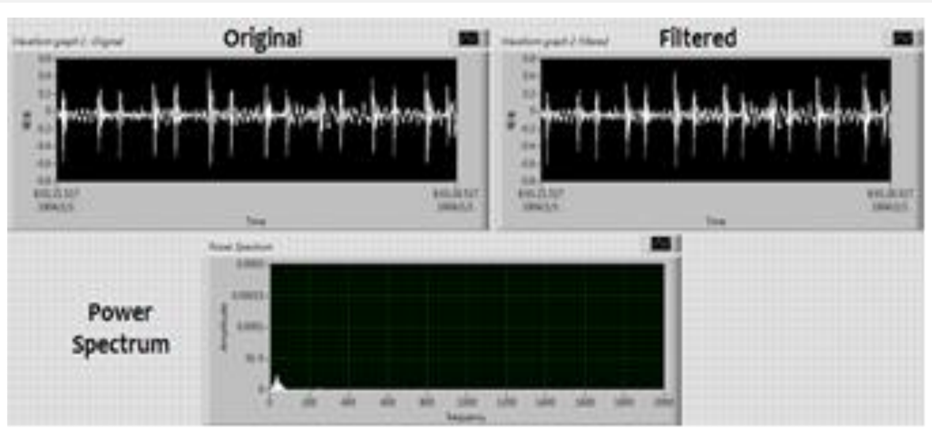

Figure 9. Waveform of normal heart sound

Last but not least, this paper also proposed a brief idea on self-screening property which is shown in Figure 9. In the figure, the power spectrum of the acoustic signal is generated by LabVIEW which shows the intensity value of the signal in different frequency.

Acknowledgements

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References

[1] F. d. L. Hedayiohlu, “Heart Sound Segmentatioin for Digital Stethoscope Integration,” *University of Porto* , 2009.
[2] Y. H. M. S. Ying C.W., “ A Portable ECG Signal Monitor and Analyzer,” *IEEE*, 2008.
[3] P.J. Arnott, G.W. Pfeiffer and M.E Tavel, “Spectral Analysis of Heart Sounds: Relationships between Some Physical Characteristics and Frequency Spectra of First and Second Heart Sounds in Normal and Hypertensive,” J, Biomed Eng. 1984, Vol.6, April