Development of Low Cost Computer Based Heart Rate Monitor

Memoona, Iqra Mehmood, Dr. Muddassar Farooq, Tariq Mehmood
Department of Electrical Engineering, Institute of Space Technology,
1, Islamabad Highway, Islamabad, Pakistan memoona91@yahoo.com, iqra_pmc@hotmail.com, muddassar.farooq@gmail.com, tariq47@msn.com

***Abstract*-- Irregular heartbeat rate might be an indication of various heart diseases [1]. The major tools presently being used for heart monitoring are either expensive or give less diagnostic information. Keeping this in view a low cost computer based heart monitor is developed which consists of signal acquisition and signal processing hardware and signal processing, displaying and storing software. The system is tested on 15 subjects and the accuracy came out to be 98.54%. It can be efficiently used to get the heart rate and amplitude versus time plot of the heart's sound signal.**

***Keywords*-- Phonocardiogram, Arrhythmia, Heart rate monitor**

I. INTRODUCTION

The number of heart problems is increasing day by day because of the fast growing unhealthy lifestyle. It is necessary to monitor the heart rate of the cardiac patients on regular basis. The most commonly used tool for this purpose is manual stethoscope which can be used to hear the heart sound only [2]. This sound cannot be further manipulated digitally using the simple stethoscope. There are digital beat counters available also but the waveform called the phonocardiogram is more revealing than just the count. Another important technique for the heart patient monitoring is ECG which displays the electric signal produced by the heart on the screen but it is expensive and require experts to carry out the examination. The developed system is a low cost and a portable heart monitor which is interfaced with a personal computer to exploit its processing power, storage capacity and large screen. The system gets the power from the USB port of the PC instead of the external batteries.

II. PHYSIOLOGY OF HEART

Human heart is a muscular organ consisting of four chambers i.e. two atria and two ventricles. The blood flow is controlled by various valves. The atrioventricular valves (bicuspid and tricuspid) prevent the backflow of blood to atria once it has entered the ventricles. Similarly the semilunar valves prevent the blood flowing back into the ventricles from lungs and the body. Fig. 1 demonstrates the structure of human heart. [3]

The deoxygenated blood from all over the body comes into the right atrium and then to the right ventricle from where it is pumped towards the lungs through pulmonary artery. The oxygenated blood from the lungs is transported back to the left atrium through pulmonary vein, passes into the left ventricle and is pumped to the whole body through aorta.

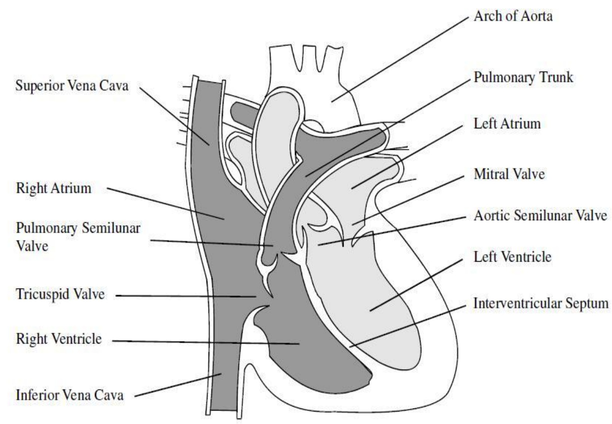

Fig. 1 Structure of Heart

The pumping of the blood towards the lungs and the body takes place as a result of the simultaneous contraction of the ventricles which is termed as systole whereas the relaxation of the ventricles is termed as diastole. At the start of the systole the atrioventricular valves close producing a "lub" sound or S1 whereas at the beginning of the diastole the "dub" sound or S2 is produced due to the closure of the semilunar valves. [4], [5]

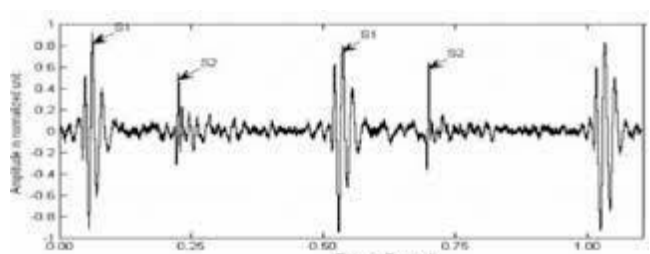

Fig. 2 A Phonocardiogram showing systole (S1) and diastole (S2)

III. SYSTEM DESIGN

The developed system is based on two parts- the hardware and the software. The hardware section consists of a sensor to pick the heart signal, analog signal processing circuitry and a PC/Laptop, while the software section consists of signal acquisition and analysis algorithm. The two sections are briefly described below.

A. Hardware Design

The concept of phonocardiography is used to design the system hardware. A very sensitive electret condenser microphone is inserted in the stem of stethoscope to acquire the heart signal. This signal is first amplified and then filtered to obtain the desired frequency range. Adult heart frequency ranges from 20Hz to 100Hz [6]. Fig. 3 shows the complete system block diagram.

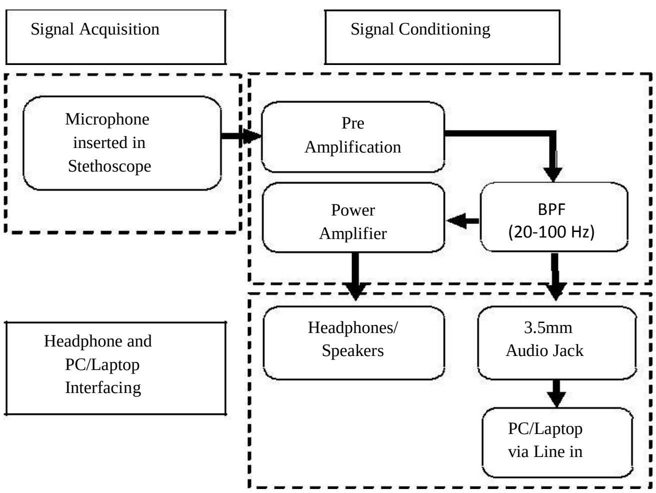

Fig. 3 Hardware Block Diagram

B. Software Design

Signal from the hardware is then fed to the laptop via sound card. MATLAB has been used for the analysis of heart signal in software. MATLAB GUI has been designed for the testing of the developed system. In this GUI, different features like play, record, save, load signal are provided.

In MATLAB, .wav file of the acquired signal is processed to calculate heart rate and display plots. The signal is passed through the Butterworth FIR bandpass filter to acquire the desired frequency range i.e. 20-100Hz. After digital filtering and ambient noise reduction the phonocardiograph along with the calculated heart rate is displayed on the screen.

IV. MEASUREMENT OF HEART RATE

The signal acquired from the hardware is first divided into blocks of 1sec interval. Then all the samples are compared with the pre-defined threshold and number of peak amplitudes is determined. Using this number, heart rate is calculated.

V. NOVELTY OF THE SYSTEM

The developed system is a novel combination of the following alternatives which makes the system different from the existing ones.

A. Sensor

Low cost microphone is used instead of ultrasonic sensor to pick the heart signal from the chest of the subject.

B. Interface

The heart signal from the hardware is fed into the laptop through line-in of the soundcard. This has saved the cost of bluetooth transmitter.

C. Display

The large screen of the laptop is exploited to display the phonocardiogram along with the digital heart rate.

D. Power

The system operates independent of the batteries. It takes power from the USB port of the laptop.

E. Portability

The size and weight of the system is optimized such that it can be carried from place to place.

VI. EXPERIMENTAL RESULTS

In literature, we found that the spectrum of heart signal lies within the range of 0-200 Hz but after extensive experimentation we concluded that most of the signal strength lies within the band of 20-100 Hz. If we include the frequencies up to 200 Hz, it will contribute towards the additional noise.

Another problem we encountered was a continuous hum sound in the background of the actual signal. It was later discovered that this sound is due to the interference of 50 Hz of the mains. It was removed by implementing a notch filter at 50 Hz.

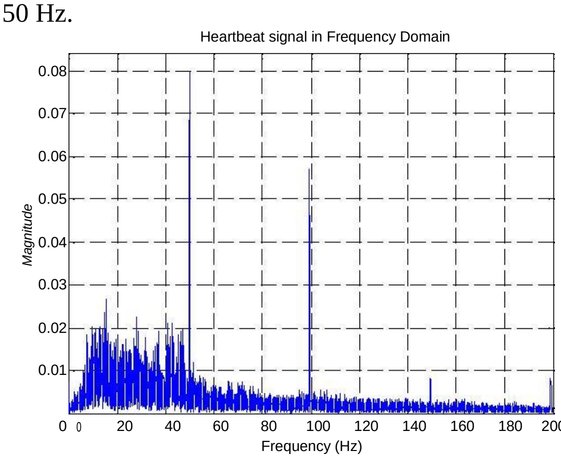

Fig. 4 Frequency Spectrum before filtering

Figure 4 shows the signal before passing through bandpass and notch filter. 50Hz and its harmonics are quite dominating in this signal. Figure 5 shows the signal after filtration. 50 and 100 Hz of the mains are eliminated through notch filters.

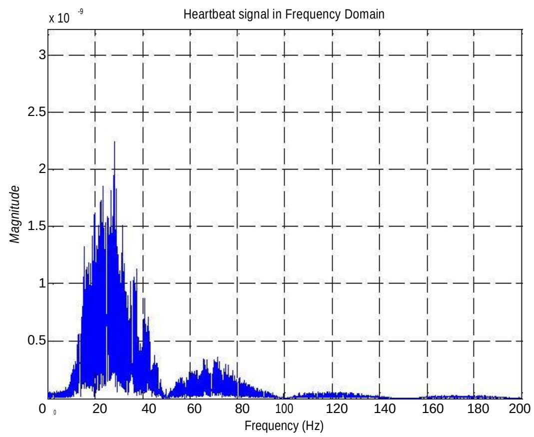

Fig. 5 Frequency Spectrum after digital filtration

The developed system has been tested on 15 subjects who belonged to the age group of 18-24 years. The results of developed system are compared with that of an electronic stethoscope. Table 1 presents the comparison between the measured heart rate by the two devices. These results are tabulated by taking the mode of five readings. The overall accuracy of the system was found out to be 98.54%.

TABLE 1
COMPARISON BETWEEN HEART RATE MEASURED BY TWO DIFFERENT DEVICES

S. #	**Age (years)**	**HR recorded by developed hardware (BPM)**	**HR recorded by Electronic Stethoscope (BPM)**	**% Error**	**% Accuracy**
1	23	62	63	1.50	98.50
2	22	77	77	0.00	100.0
3	22	77	76	1.30	98.70
4	22	74	75	1.33	98.67
5	34	66	66	0.00	100.0
6	22	79	83	4.81	95.19
7	21	76	78	2.56	97.44
8	24	77	75	2.67	97.33
9	18	86	86	0.00	100.0
10	20	78	77	1.29	98.71
11	21	86	88	2.27	97.73
12	19	89	89	0.00	100.0
13	20	86	88	2.27	97.73
14	23	68	67	1.49	98.51
15	22	56	56	0.00	100.0

JABES Analyzer is an electronic stethoscope which is used as gold standard for the comparison of the phonocardiogram. Figure 6 shows the results obtained by JABES Analyzer and figure 7 shows the waveform obtained by the developed system on MATLAB.

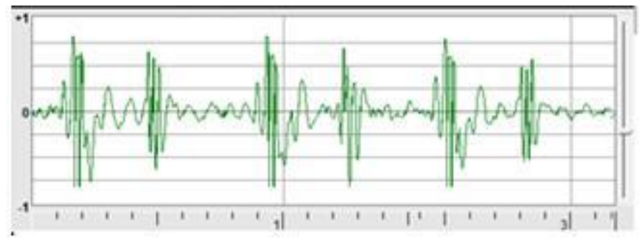

Fig. 6 Phonocardiogram acquired by the developed hardware on JABES Analyzer

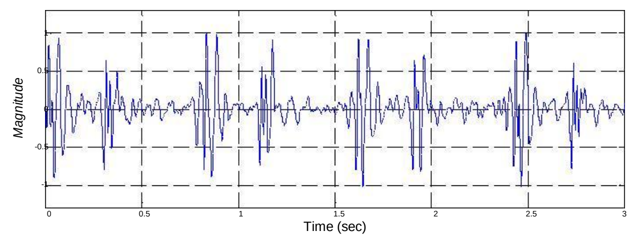

Fig. 7 Phonocardiogram acquired by the developed system on MATLAB

VII. CONCLUSION

By interfacing the developed hardware, the personal computer is converted into a heart monitor. The heart beat count is comparable to that recorded by a sophisticated electronic stethoscope (98.54%) tested on 15 subjects. The waveform is not exactly equivalent to phonocardiogram because of the body noise i.e. breathing and blood flow sounds. Further improvement can be made in future by working on the elimination of the noise to get the more accurate results.

ACKNOWLEDGEMENT

We express our profound gratitude to Dr. Muddassar Farooq and Mr. Tariq Mehmood for their guidance and encouragement throughout the development of the project. We are also thankful to all the volunteers who took time to participate in the clinical trials of our system.

REFERENCES

[1] Published in 2012,"Cardiovascular heart disease, Risk factors". Available at:http://www.world-heartfederation.org/fileadmin/user_upload/documents/Fact_sheets/2012/CVD_terms.pdf

[2] John G. Webster, 4th Edition, "Medical Instrumentation, Application and Design "

[3] Christer Ahlström , "Processing of the Phonocardiographic Signal −Methods for the Intelligent Stethoscope" Department of Biomedical Engineering, Linkoping University, Sweden, May 2006

[4] University of Nottingham, "Cardiology Teaching Package, Guide to normal heart function, and common cardiac arrhythmias". Available at: http://www.nottingham.ac.uk/nursing/practice/resources/cardiology/function/anatomy.php

[5] D. Smith and E. Craige, "Heart Sounds: Towards a Consensus regarding their Origin", Am. J. Noninvas. Cardiol, vol. 2, pp. 169-179, 1988.

[6] Chen D1, Durand LG, Lee HC, "Time-frequency analysis of the first heart sound. Part 1: Simulation and analysis", 1997