Heart Rate Variability (HRV) Measurement- A Methodological Application of Low Frequency measurement in LabVIEW

M.L Sharma, Ravi Kant Verma, Noor Fatima Rizvi, Anu Malhotra, Swati Sharma, Nipun Sharma

Summary
The applications of low frequency sound measurement in the medical field are immense. The low frequency sound signals find tremendous applications in medical filed like Low frequency Sound Therapy, Sound Surgery, Vibroacoustic Therapy, Bio-Tuning etc. The paper discusses a novel method of designing a measurement system using LabVIEW 7.0 and the designing of a data acquisition card for low frequency sound signals. This methodological approach towards measuring Heart rate variability could prove to be an extremely useful low cost solution at small hospitals and household.

Key words:
LabView, HRV, Signal Acquisition, Low Frequency Measurement.

1. Introduction

The sounds we hear in our daily life commence as a vibration in an object, it may the plucked string of a guitar, the diaphragm in a loud-speaker, the vocal chords or a bell. Sound is an example of a longitudinal or compressional wave that causes a disturbance parallel to the direction in which the wave is moving, i.e., as a wave travels from left to right then the disturbance caused by that wave is in the left-right direction. Sound is a molecular disturbance and the disturbance is caused by a vibration. Whatever is vibrating, moving rapidly back and forth, sets up compressions and rarefactions which travel outwards from the object as a compressional wave. As sound waves are a disturbance or vibration in a medium of solid, liquid, or gas it follows that where there is no medium there is no sound.
Sound is a form of energy. It travels from one place to another through a medium like air. It can also travel through other gases such as helium, and can even travel through liquids and solids. The only thing sound cannot travel through is a vacuum like space.
When an object moves back and forth, or vibrates, it pushes the air molecules next to it. As air molecules get compressed into waves, the energy is transferred from molecule to molecule until it is exhausted. That is why sounds that are farther away sound softer, as their energy fades as they travel. Sounds can be soft or loud. This characteristic of sound is called amplitude or volume. Volume measures the amount of energy in sound waves. More energy will move more air molecules and will sound louder. Less energy will move fewer air molecules and will sound softer. The amount of energy in a sound wave is measured in decibels (dB).
Talking about the sounds in medical applications, the one that first comes to mind is the heart sound which is commonly known as “Lub-Dub” sound. The sound produced by the heart is of very low frequency and the instrument commonly used to hear the heart sounds is Stethoscope. Stethoscope has been employed for different applications in the medical field such as pulse rate measurement, blood pressure measurement etc. But the most common application of the stethoscope is the heart sound measurement.

2. Heart Sound and Abnormalities in Heart Sound

The technique of listening to sounds produced by the organs and vessels of the body is called auscultation. The heart sounds actually occur at the time of closure of major valves in the heart. The snapping action of the veins of the heart valves produces almost no sound because of the cushioning effect of the blood. The main cause of heart sound is the vibrations set up in the blood inside the heart by the sudden closure of the valves. With each heart beat, the normal heart produces two distinct sounds that are audible in the stethoscope which are often described as “lub-dub”. The “lub” is caused by the closure of the atrioventricular valves, which permit flow of blood from the atria into the ventricles and also prevent flow in the reverse direction. Normally, this is called the first heart sound and it occurs approximately at the time of the QRS complex of the vector cardiogram. The dub-part of the heart sound is called the second heart sound and is caused by the closing of the semi lunar valves, which release blood into the pulmonary and systemic circulation systems. This second heart sound occurs about the time of the end of T wave of the electrocardiogram. The third heart sound is sometimes heard especially in young adults. This sound occurs from 0.1 to 0.2 seconds after the second heart sound. An atrial heart sound which is not audible but may be visible on a graphic recording occurs when the atria actually contract, squeezing the remainder of the blood

Manuscript received February 5, 2011
Manuscript revised February 20, 2011

into the ventricles. The inaudibility of this heart sound is a result of the low amplitude and low frequency of the vibrations.
In abnormal hearts, additional sound called murmurs are heard between the normal heart sounds. Murmurs are generally caused either by improper opening of the valves or by regurgitation which results when the valves do not close completely and allow some backward flow of blood. In either case, the sound is due to high velocity blood flow through a small opening. Another cause of murmurs can be a small opening in the septum, which separates the left and right side of the heart .In this case, pressure differences between the two sides of the heart force blood through the opening, usually from the left ventricle into the right ventricle bypassing the systemic circulation.
There is also a difference in frequency range between normal and abnormal heart sounds. The first heart sound is composed of energy in the range of 30 to 45 Hz, in which most of the sound is below the threshold of audibility .The second heart sound is usually higher in pitch than the first, with maximum energy in the 50 to 70 Hz range. The third heart sound is an extremely weak vibration, with most of its energy at or below 30 Hz. Murmurs, on the other hand, often produces much higher pitched sounds. One particular type of regurgitation, for example, causes a murmur in the 100- to 600 Hz range.

3. Low Frequency Sound Measurement in Medical Application

As the low frequency sound applications are numerous in number specifically in medical applications, so we decided to work on biomedical based heart sound measurement system. The objective of the work presented in the paper is to develop a Data Acquisition Card which will acquire the sound signal of the heart from the stethoscope which is then interfaced with the computer, thus providing the visual signal. The signal obtained in the computer is then viewed using the coding developed in LabVIEW 7.0. After the project completion the areas of improvement will be in the hospitals, for the doctors and for patients under examination.

4. System Overview

The system mainly consists of the sensor which can sense and pick up the heart sounds for which acoustic stethoscope has been used. In order to acquire the signal, data acquisition card has been designed, details of which are discussed in the subsequent chapters. Data acquisition card mainly consist of amplification and filtering stages followed by the interfacing circuit so as to transfer the acquired signal to the computer. For this parallel port communication has been employed. Finally, LabVIEW 7.0 is used to display the acquired signal on the computer.
In order to complete the project the main requirements are summed up as below:

1. Sensor to Sense Heart Sound Simple acoustic stethoscope together with the microphone has been used as the heart sound sensor. The signal is picked up by the stethoscope and given to the data acquisition card via the microphone.
2. Data Acquisition Card to Acquire the Sensed Heart SoundData Acquisition card consisting of pre- amplification, filtering and power amplification stages is designed in order to acquire and condition the heart sound picked by the stethoscope.
3. Interfacing Circuitry to Transfer the Acquired Signal to the Computer Interfacing circuit consist of Analog to digital converter and parallel port communication to transfer the digitized signal to the computer.
4. Software to Display the Transferred Heart Sound Signal National Instrument's LabVIEW 7.0 is used to display the transferred heart sound signal on the computer screen.

5. Methodology

For the implementation of the work presented in the paper i.e. acquiring the heart sound, hardware as well as software modules are required. The first one is the hardware which is being used to pick a low frequency sound signal and giving it to PC after necessary signal conditioning and digitization. Once the signal has been picked up by the personal computer it is being displayed using National Instrument's LabVIEW 7.0.
The hardware design for this project consisted of building a data acquisition card. The stethoscope microphone circuit picks up the heart sound signal from the heart and the data acquisition circuit acquires, amplifies and filters this signal. After the acquisition of the heart signal from the patient, the data Acquisition card has to be interfaced with the computer and the signals are viewed on the monitor of the computer using National Instrument's LabVIEW 7.0

In nutshell, the work which has been done includes:

- Hardware Circuit Design of Data Acquisition Card
- Hardware Design of Interfacing Circuit
- Interfacing of DAC With the Computer

- Software for Viewing the Heart Signal on Computer

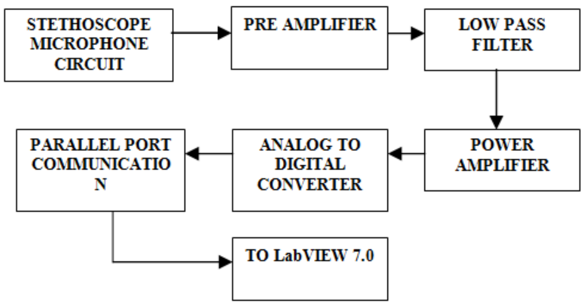

Fig.1 System Block Diagram

In this paper, we'd like to share the work on the development of the data Acquisition Card.

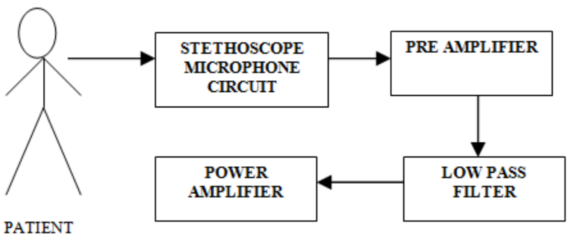

Fig.2 Block Diagram of Data Acquisition Card

The circuit has a number of component parameters that must be met in order to operate it effectively. Firstly, the first stage of amplification i.e. the pre amplification stage must have high input impedance and low input bias current. High input impedance in an amplifier circuit helps in minimizing loading effects. Loading occurs when the gain of the second stage of an amplifier affects the gain of the pre amplifier. This loading can result in a distortion of the output signal. The flow diagram below is of Data acquisition card that shows the pre amplification, filter and power amplification stages. Apart from this , it has the stethoscope and the microphone which is being used to pick up the heart sound signal from the patient(also shown in the figure).Thus the DAC requires the pre amplifier, low pass filter and the power amplifier to fulfill its functionality.

6. Software Implementation Using LabView 7.0

After the acquisition, necessary signal conditioning and interfacing with the computer, the signal is displayed on the computer screen using National Instrument's LabVIEW 7.0. The software requirements of the project are mentioned hereunder:

- To get the data coming on parallel port
- To display the data in graphical form

Keeping the above requirements in mind software coding is developed in LabVIEW 7.0 in which different virtual instruments have been used such as those for parallel port data communication etc. LabVIEW 7.0 is a graphical programming language which uses icons instead of lines of text to create applications, so a block diagram has been developed to acquire the signal from the parallel port of the computer and display the same on the screen of the computer. The Front panel is developed where the signal can be seen in the wave form and its numerical value has also been shown. VI to save the signal to file has also been developed with the help of which the signal can be saved and retrieved any time for future reference. In this way, the record of the patient's heart sounds can be well maintained. The following pages show the block diagram and the front panel of the software module developed in LabVIEW 7.0.

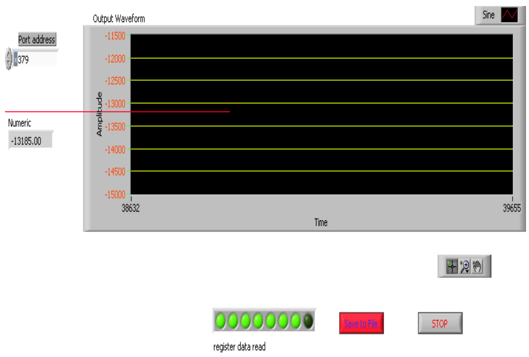

Fig.3 Front Panel: User Interface of the Heart Sound Measurement.

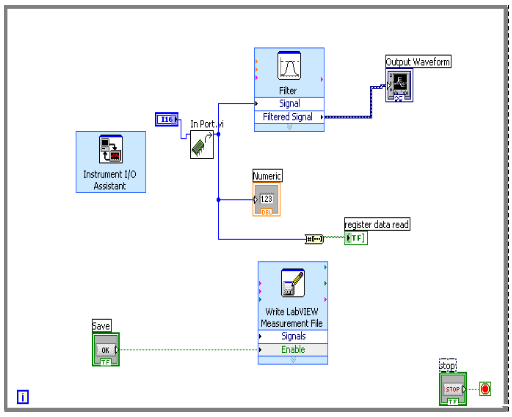

Fig.4 Block Diagram of the Heart Sound Measurement

Fig.5 Complete Heart Sound Measurement System interfaced with a computer System.

7. Results, Conclusions and Future Scope

An attempt has been made to interface the stethoscope with the virtual instrument in LabVIEW 7.0 and display the heart sound signal on computer screen after acquiring the same using Data Acquisition Card through parallel port of the computer. The design of Data Acquisition Card (DAC) circuit and Interface circuit was successful which was seen on the computer screen. Filtering techniques have been utilized to attenuate unwanted noise to highlight the heart sound signal in which considerable amount of success has been achieved. After the completion of the project it can be concluded that the areas of improvement will be in the hospitals, where the heart sound data of the patient can be stored in a computer in a file format and can be retrieved whenever required so that a case history can also be prepared as and when required.

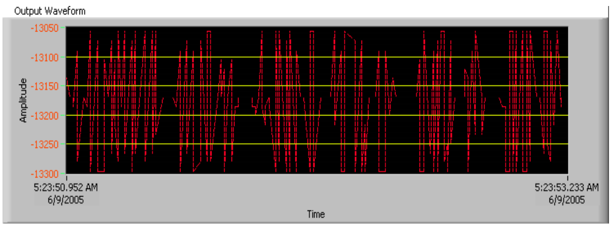

Fig.6 Signal obtained without band pass filter

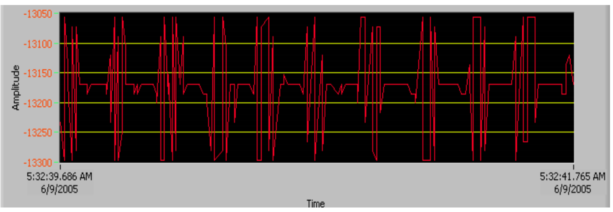

Fig7. Signal obtained with band pass filter

The system which has been designed can undergo some advancement which would make the device to be able to be deployed in critical conditions. A higher resolution Analog to Digital converter would provide more accurate results. Noise which is the main cause of signal distortion can also be reduced by a considerable amount for good signal quality and signal enhancement. General purpose display circuitry can be designed so that the signal can easily be viewed on Cathode Ray Oscilloscopes etc. The incorporation of USB communication capabilities would enhance the device. Currently parallel port is being used for data transfer. The higher data rate would also allow the transfer of more precise measurements. More sensitive microphone can also be employed so that clearer results can be obtained.

References

[1] http://en.wikipedia.org/wiki/stethoscope
[2] Biomedical Instrumentation and Measurements, second edition by Leslie Cromwell, Fred J. Weibell and Erich A. Pfeiffer.
[3] http://www.ymec.com/hp/signal2/thema02.htm
[4] http://www.ni.com/dataacquisition/
[5] National Instrument’s Getting Started with LabVIEW Manual, April 2003 edition.
[6] National Instrument’s LabVIEW Measurements Manual, April 2003 Edition.
[7] http://www.computerhope.com/jargon/d/dbconnec.htm
[8] http://www.heartsite.com/html/echocardiogram.html
[9] http://www.philtulga.com/MSSActivities.html

Authors

Prof. M.L Sharma is working as a Proferssor and Head of Department (ECE) in BGIET, Sangrur. He is enrolled as a Ph.D Candidate in Delhi University and is has expertise in Radio Frequency, Antennas and Optical Communication.

Mr. Ravi Kant Verma is working as an Assistant Professor in the department of Electronics and Communication Engineering in Chitkara University, Baddi. His area of expertise is Analog Electronics Design.

Ms.Noor Fatima Rizvi is working as a Faculty in Manav Rachna University, Faridabad,India. Her interests include Instrumentation, LabVIEW.

Ms. Anu Malhotra is working as Faculty in Jamia Milia Islamia University, New Delhi. Her interests include DSP and embedded controllers.

Ms.Swati Sharma is working as Assistant Professor and Head(ECE Department), in Universal Institute of Engineering and Technology, Punjab. She is a Post Graduate in Engineering in Instrumentation from Panjab Univeresity Chandigarh. Her interests include designing low cost data acquisition systems.

Mr.Nipun Sharma is working as a Faculty in Chitkara University and has interest in Data Acquisition, Digital Signal and Image Processing.