Two-Channel Data Acquisition Unit for Heart Sound Analysis

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Abstract—**This paper describes the development of a data acquisition system for the electrocardiogram (ECG) and the phonocardiogram (PCG). Diagnosing heart sounds and heart murmurs using the stethoscope is an established practice clinically. However it requires considerable experience and training, to ensure validity and reproducibility. Echocardiography provides more definitive diagnosis in this respect but it is expensive and not widely available. With the advancement in personal computers (PC), this data acquisition unit interfaces with any desktop or notebook PC and functions as a virtual instrument for the heart diagnostic system. The ECG has been a reliable reference for the cardiologists to determine the first (S1) and second (S2) heart sound. Transformation of the heart sound signal using DSP technique, that is the Instantaneous Energy (IE) and Instantaneous Frequency (IF) for heart diagnostic can be a new approach for cardiologists. Furthermore, combining phonocardiogram with ECG for on-line diagnosis may be an important way forward. This paper describes the development of two channel acquisition system for heart diagnostic base on DSP technique.**

***Keywords-** phonocardiogram; electrocardiogram; data acquisition; heart diagnostic*

I. INTRODUCTION

Diagnosing heart diseases with a stethoscope and ECG are two fundamental methods because of its efficiency, simplicity and non-invasive property [1]. However it takes a skilled and experienced doctor to be able to discover the heart condition by using a stethoscope [2]. With the advancement of computer systems in terms of its reproducibility, consistency and speed, it is vital in aiding the cardiologists in diagnosing tasks.

The heart sounds is produced from the mechanical actions of the heart. These mechanical pumping actions correlate with the electrical activity of the heart, that can be picked up by the ECG. The heart sounds repeat with two normal sounds, that is the first heart sound (S1) and the second heart sound (S2). However, there could be the third and fourth heart sound (S3 & S4) in some conditions. The heart sounds and ECG signals are depicted in Figure 1. An algorithm for automated detection of S1 and S2 for the purpose of segmentation is presented by [1]. This segmented data can be fed into neural networks for cardiac abnormalities disorders detection.

Figure 1, shows that S1 occurs just right after the QRS complex of the ECG. S2 occurs towards the end of the T wave, S3 which has relatively lower energy occurs right after S2, and S4 occurs after the P wave [2]. This shows that the ECG can be utilized for distinguishing between the heart sounds.

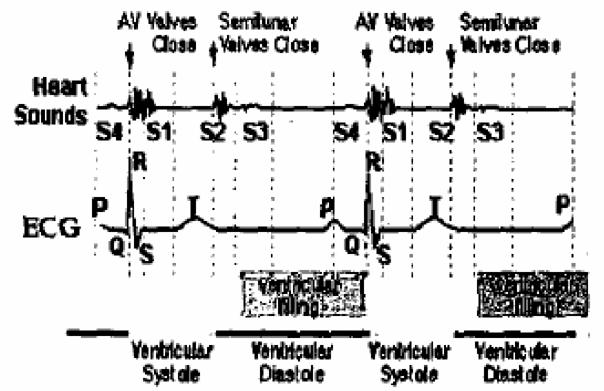

Figure 1: The heart sounds in correlation with the ECG

A data acquisition unit capturing the heart sound and the ECG simultaneously may provide a diagnostic advantage. It is crucial in developing a database of these signals for segmentation, neural network training and recognition. It has to be a low cost device and it will be useful tool for early detection of cardiac disorders and not for detailed diagnostic. Its low cost feature will make the system affordable even in small clinics.

A wireless heart rate monitoring system based on heart sound is developed by [3]. Instead of using the three electrodes ECG to get the heart rate, the heart sound is utilized. The design of the system is geared towards portability and single wire signal source that is the stethoscope. However it has no intentions of diagnosing the heart sounds other than just measuring the heart rate.

The virtual instrument developed by [4] has almost similar properties as proposed in this paper. However [4] puts together LabVIEW plug-in data acquisition board and custom designed two-channel bio-signal amplifiers whereas the proposed system has its own developed data acquisition unit and bio-signal conditioners. The advantage of the proposed system over that is its cost is not much.

Both [5] and [6] developed PCG diagnosis systems on personal digital assistant (PDA) platform. [5] implements the Bluetooth wireless technology to acquire data from unwired patient while [6] inputs the heart sounds directly from the PDA's microphone jack. Both of these systems however, do not utilize the ECG for segmentation and the diagnosis is done visually on the transformed heart sound signals such as the spectrogram.

II. THE SYSTEM ARCHITECTURE

Figure 2 illustrates the block diagram of the system. It consists of three hardware modules, the ECG signal conditioning, heart sound signal conditioning and the two-channel data acquisition unit. Both the signal conditioning modules consists of amplifier and analog filter circuits.

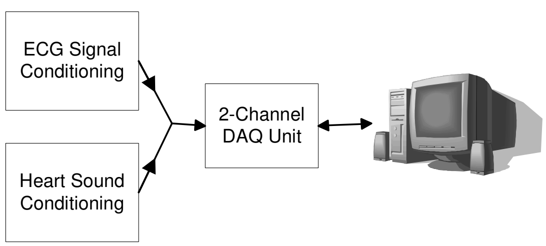

Figure 2: Main block diagram of the system

The overall gain for the ECG amplifier is 1000, while its filtered signal bandwidth ranges from 0.05Hz to 100Hz. The module includes the right-leg drive for 50Hz power-line suppression as well as a return path for the ECG. The module also contains isolation amplifier and isolated power supply to avoid the patient from high current feedback which ensures safety. This is depicted in figure 3. A Bessel low pass filter is implemented since it has a flat group delay, which will not distort the original signal of interest.

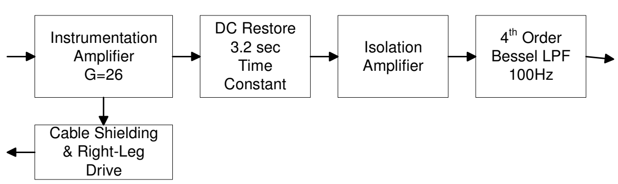

Figure 3: ECG signal conditioning block diagram

The heart sound conditioning module as in figure 4 has a fixed gain of 30 and captures its signal from an electronic stethoscope with volume control. The band-pass filter cut-off is between 20Hz and 1000 kHz.

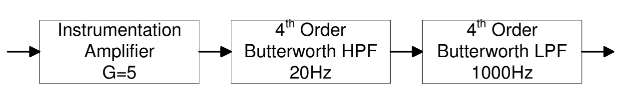

Figure 4: Heart sound signal conditioning block diagram

Figure 5 illustrates the acquisition block diagram as implemented in the system developed. It has 16-bit resolution analog to digital converter (ADC). The output of the ADC is fed directly to the parallel port interface. The microcontroller in this implementation is only as a digital control to the analog multiplexer, ADC and parallel port interface. The highest frequency of interest in both signals is 1000Hz. Therefore, with reference to Nyquist sampling theorem, the data acquisition unit is programmed to do 2 kHz sampling for each channel. This is achieved through the microcontroller firmware programming.

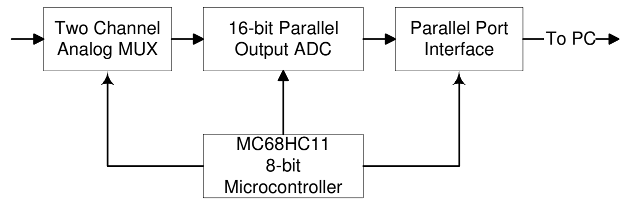

Figure 5: PC acquisition unit block diagram

Figure 6 shows the flowchart for the firmware programming done in MC68HC11 assembly language. Each 16-bit conversion results needs two transfers to the parallel port. This is because only 8-bit output is available on the ADS7805 ADC and they are connected to the data lines of the parallel port. The high or low byte output from the ADC can be selected by the BYTE pin on the ADS7805 by the microcontroller.

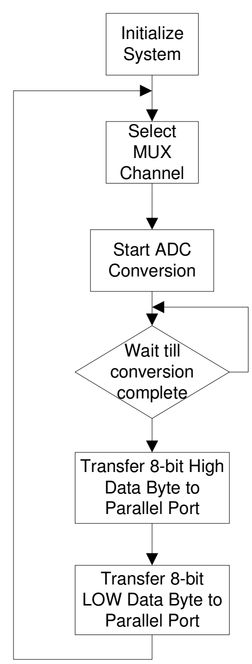

Figure 6: Flowchart for acquisition unit firmware

III. RESULTS

Figure 7 depicts the PC software for real-time plotting. The transformation segmentation of heart sound and ECG as in [1] is done offline with five seconds of the latest data. The signal in figure 7 is acquired from a normal individual. It can be observed that the S1 and S2 occur at specific points of the ECG mentioned earlier.

The developed PC software also includes IE and IF transformation of the heart sound. From the IE of the heart sound, S1 and S2 can be identified without utilizing the ECG waveforms. Figure 8 shows the IE transformation of the heart sound from the same normal subject in figure 7. Figure 9 show the heart sound acquired from a patient with S4 abnormalities. IE transformation of the heart sound highlights the S4 which cannot be clearly seen from the raw signal. The ECG markings clearly show the occurrence of the S4.

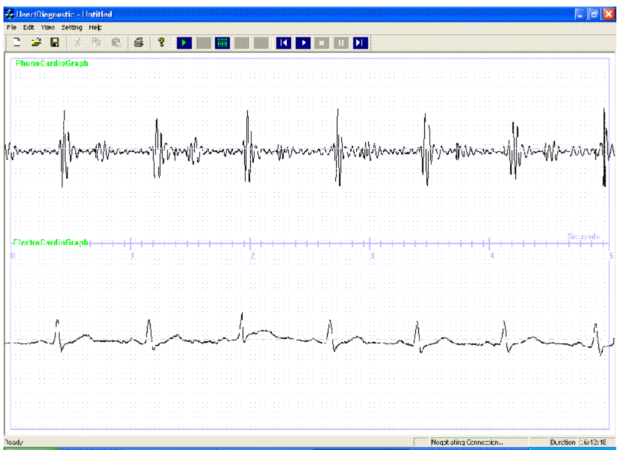

Figure 7: Main software interface. Five seconds heart sound and ECG captured from a normal subject.

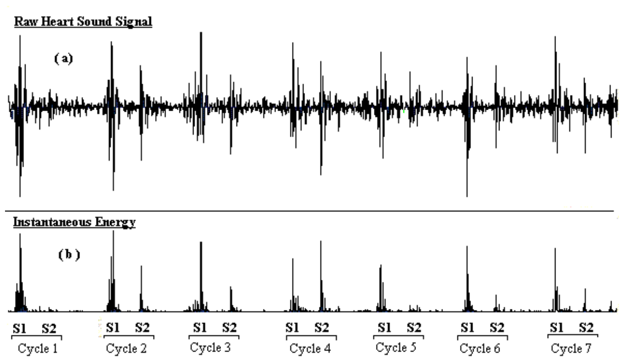

Figure 8: The heart sound and its IE representation from a normal subject

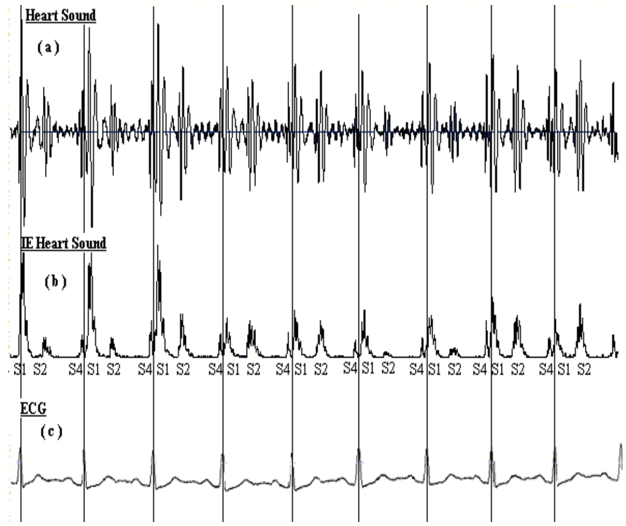

Figure 9: The heart sound, its IE representation and ECG with S4 possibilities

IV. CONCLUSIONS

An instrument for recording and analyzing the heart sound with the aid of ECG has been developed. Automated segmentation of the heart sounds can be done by identifying the QRS peak of the ECG. However, S1 and S2 detection can be done using the IE and IF DSP technique. In spite of that, the ECG signal will be maintained to confirm the cardiologists of the DSP technique implemented. Furthermore, advanced DSP technique can be explored for heart diagnostic with the aid of the two-channel heart sound and ECG acquisition system.

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