Digital Stethoscope for Heart Sounds

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ABSTRACT
The stethoscope has been used for many years, and has been very effective to diagnose certain cardiologic and pulmonologic sounds. For many years healthcare professionals would listen quietly to patients internal organs so they could diagnose from specific sounds of such internal organs. The objective is to develop a Peripheral Interface Controller based digital Stethoscope to capture the heart sound. The proposed designed device consists of following hardware stages: Front-end pickup circuitry, PIC18F2550 microcontroller, (128×64) graphic LCD and a Serial EEPROM. The captured data can be sent to PC for software analysis using LabVEIW. A digital stethoscope would help healthcare professional record their findings on a Serial EEPROM. Once the data is stored, the healthcare professionals can hear and plot the graph. This would be quick and more effective since there is a visual and audio representation to diagnose such cardiologic sounds.

General Terms
Measurement, Design, Bio-Medical.

Keywords:
Digital stethoscope, Heart sounds, PIC18F2550

1. INTRODUCTION
The current practice among the physicians is to use a stethoscope to determine the condition of the heart based on technique known as auscultation. This technique is very subjective because the records provided could be interpreted in several ways depending on how the physician interprets the sounds. The objective is to develop a PIC based

digital stethoscope to capture the Heart sound. The discussed design [1] of the device consists of following hardware stages: Front-end pickup circuitry, PIC18F2550 microcontroller, (128×64) graphic LCD and Serial EEPROM. The software time and frequency domain analysis of the heart sound will be done using LabVIEW. The objective of this work is to develop a technique that can assist a trained physician to classify the heart sounds and murmurs. The procedure suggested would provide the graphical plot of the heart sound with respect to the time, the category of the murmurs and the types of common heart disorder faced by the patient. It will also provide the permanent record of the analysis. The data collected by the digital stethoscope can be processed and analyzed. It allows early detection of the common heart disease.

2. HEART SOUNDS
An important diagnostic tool is the analysis of heart sounds which are normally produced by various mechanical activities of the heart during the heart cycle [2]. The principle cause of heart sound can be from the vibrations set up in the blood inside the heart by the closure of valves and leakage of blood flow. There are two classical sounds of heart, known as the first (Lub) and the second (Dub) sound and also there exists two other sounds, known as third and fourth sounds which can be detected by graphical recording.The first sound occurs at the onset of ventricular systole and is primarily composed of energy in the 30 Hz - 45 Hz range. It is caused by the closure of the atrioventricular valves and the vibrations set up in the valve leaflets due to increase in the intraventricular pressure. The second sound occurs at the onset of diastole and lies with maximum energy in the 50 Hz - 70 Hz range with higher pitch. It is caused by the closure of the semi-lunar valves in the aorta and pulmonary artery. The third sound, particularly heard in young adults takes place just after the second sound and coincides with the opening of the atrioventricular valves and is caused by the sudden rush of atrial blood into the ventricles. It is a weak vibration with its energy level at or below 30 Hz. The fourth sound also known as atrial sound is caused by the contraction of the atria and the rush of blood into the ventricles and has a low energy level below 30 Hz.

Thus, the heart sound information can be related as follows:

first sound — mitral valve closure and tricuspid valve closure

second sound — aortic and pulmonary valves closure

third sound — termination of ventricular filling

fourth sound — atria contract

Murmurs, which are additional sounds are heard in case of abnormal hearts and are caused either by improper opening of valves, regurgitation or due to a small opening in the septum, by passing the systemic circulation. It lies within a range of 100 Hz-600 Hz.

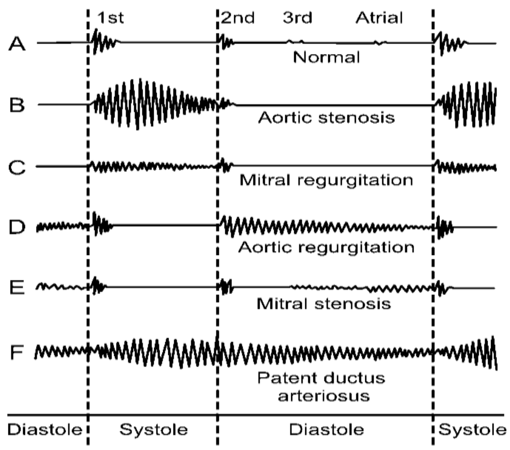

Figure1: Normal and abnormal heart sounds

3. SYSTEM DESCRIPTION

The proposed system [1][4] consists of the following hardware components: 1) Front end pick up circuitry – preamplifier, filter and final amplifier with variable gain 2) PIC18F microcontroller 3) Graphic LCD, 4) Serial EEPROM 6) USB interface. These modules have been shown in figure below

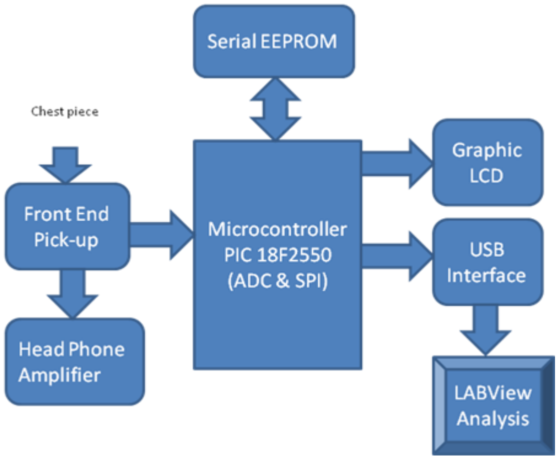

Figure 2: Block Diagram of system

3.1 Front End Circuitry

The front end circuit is shown in Figure 2. It consists of microphone fitted chest piece which picks up the heart sound.

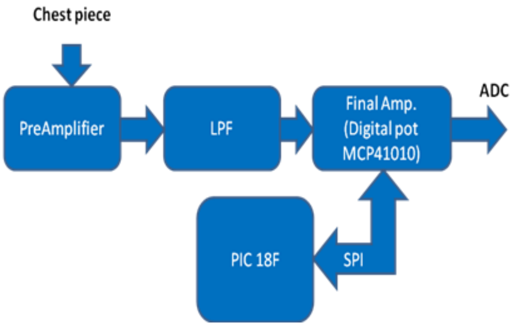

Figure 3: Front End Circuit

The output of the microphone is fed to the pre-amplifier, which provides initial amplification and better hum rejection. The output of the preamplifier is fed to an active low pass filter with cut-off of 1.2KHz. The output signal from the filter is processed by Head Phone amplifier, so as to get audible heart sound.
Digital potentiometer from Microchip is in the feedback of the final amplifier so as to provide sufficient gain to the captured signal for the ADC. It is interfaced via Serial Peripheral Interface to the PIC18F controller. The physician will be provided with the gain button which can be adjusted to get a clear waveform on the LCD.

3.2 Microcontroller

The PIC18F2550 forms the central part of the system. The whole system is build around it. The MikroC compiler developed by mikroelectronica Inc. is used for programming.
Some Features [5]:

- Program Memory 32KB(Flash)
- CPU Speed 12 MIPS
- RAM Bytes 2,048
- Digital Communication Peripherals 1-A/E/USART, 1-MSSP(SPI/I^2C)
- ADC 10 channel, 10-bit
- Full Speed USB 2.0
- Operating Voltage Range 2 to 5.5 V

3.3 Graphic LCD

Graphic LCD displays the data directly in the form of wave forms as well as character. The user can visually observe the data and make out his decision for the state of his health. JHD12864 was selected because of its moderate advantages like low cost compare other parallel graphical display.

3.4 Memory

Data collected from front end i.e. sensor should be stored in memory for longer time and can be utilized for diagnosis purpose by physicians later on. AT24C1024 EEPROM is used as storage device. The AT24C1024 provides 1,048,576 bits of serial electrically erasable and programmable read only memory (EEPROM) organized as 131,072 words of 8 bits each.

4. IMPLEMENTATION

The following circuits have been simulated using Proteus and also hardware is implemented for them.

4.1. Front End Pick-up

As discussed before the front end pick-up circuit consists of Pre-amp, Filter and Variable gain amplifier. The Heart Sounds are picked up using a microphone embedded inside the chest piece tubing and from there it is given to the pre-amplifier for initial amplification.

4.1.1 Preamplifier and Filter

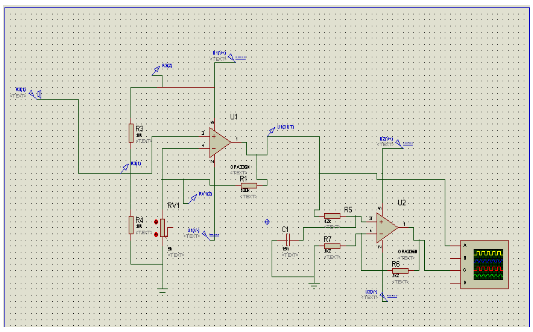

Figure 4: Proteus circuit for Pre-amp and LPF

The preamplifier provides initial amplification and better hum rejection. The output of the preamplifier is fed to an active low pass filter with cut-off 1.2 KHz.

4.1.2 Digital Potentiometer Interface

Potentiometer from Microchip is used to provide sufficient gain to the captured signal so that it will be in range for the inbuilt Analog to Digital convertor of PIC. It is interfaced via SPI to the pic18F2550. A push button is connected to the interrupt pin of PIC. As the button is pressed an incremental 8 bit value is sent to the pot and gain of amplifier increases.

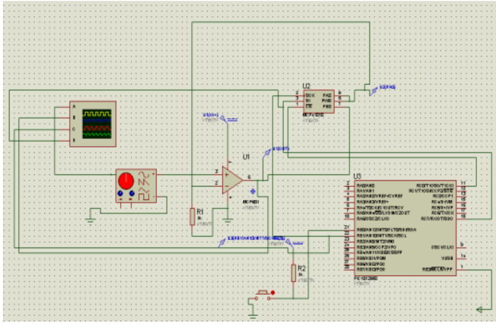

Figure 5: Proteus Schematic for Digital pot. interface

4.2 Graphic LCD interface

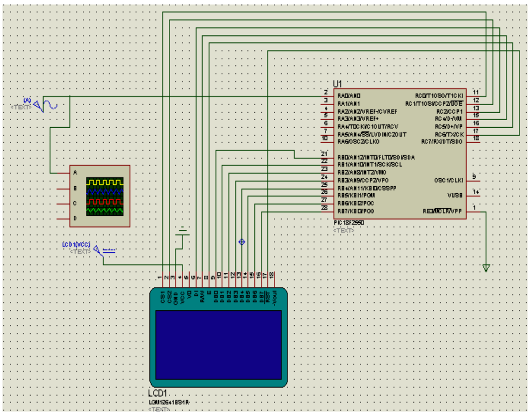

Figure 6: Proteus circuit for GLCD Interface

The Ampire 128X64 parallel GLCD available with proteus has been interfaced with PIC18F2550. The simuation is tested with the picked up heart sounds, saved as wave file using Cool Edit Pro software and given as input to the internal ADC and is displayed on the GLCD.

4.4. EEPROM Interface

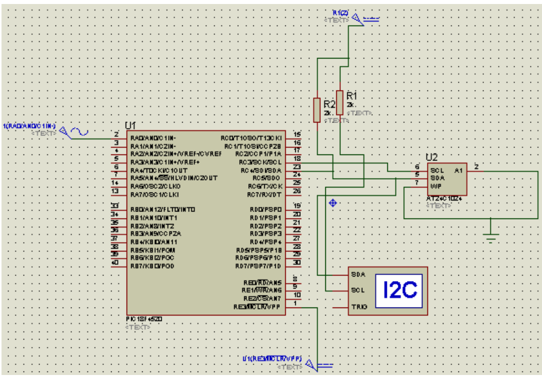

Figure 7: EEPROM interfacing circuit

EEPROM AT24C1024 is interfaced with the PIC using I^{2}C protocol. The heart sound captured are stored and made available as required by physician.

5. RESULTS

Some of the results obtained from the work done are discussed

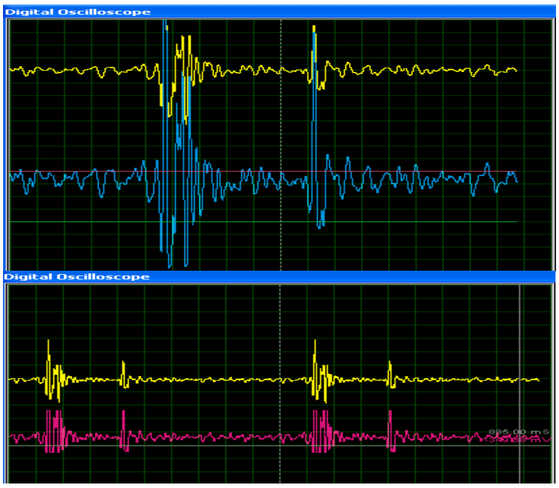

Figure 8: Proteus simulation for Front End ckt.

The amplifier and filter is tested with captured heart sounds using Cool Edit Pro. The output waveform has the gain and cut-off frequency as desired.

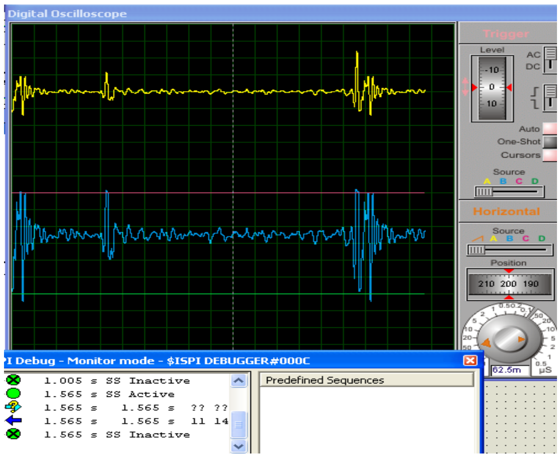

Figure 9: Simulation output for Final amplifier

the fig.9 above shows the SPI debugger window, which shows the change in the data sent to digital pot. with every key press and also the variation in the output waveform can be seen.

These are heart sounds after A/D conversion displayed on the Graphic LCD and also corresponding display obtained with Cool Edit Pro software are compared.

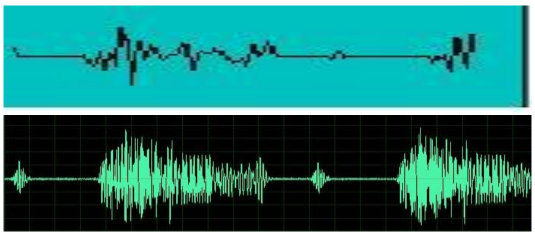

Figure 10: Case of Aortic Regurgitation

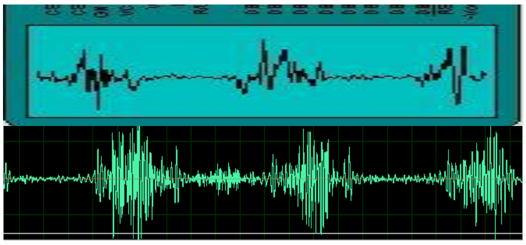

Figure 11: Case of Aortic Stenosis

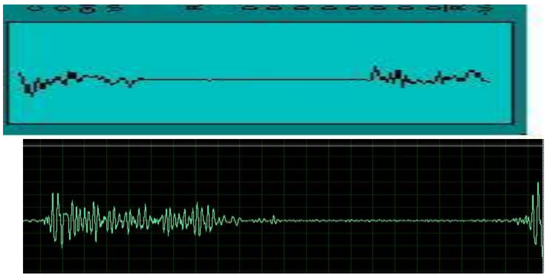

Figure 12: Case of Mitral Regurgitation

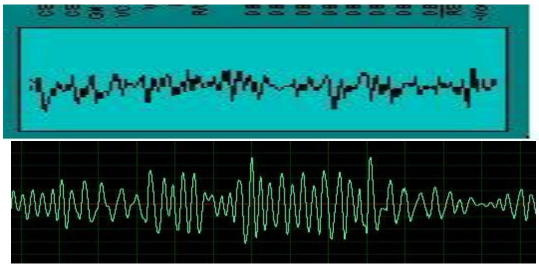

Figure 13: Case of Patent Ductus Arteriosus

6. LabVIEW ANALYSIS

The LabVIEW analysis is done on the heart sounds inputted via the microphone input of the Personal Computer. The signal is accepted and passed through a band pass filter to remove noise and plotted on the waveform graph. Also provisions are done for the physician to record and retrieve the signal for future references. The Front Panel and the Block Diagram are shown below.

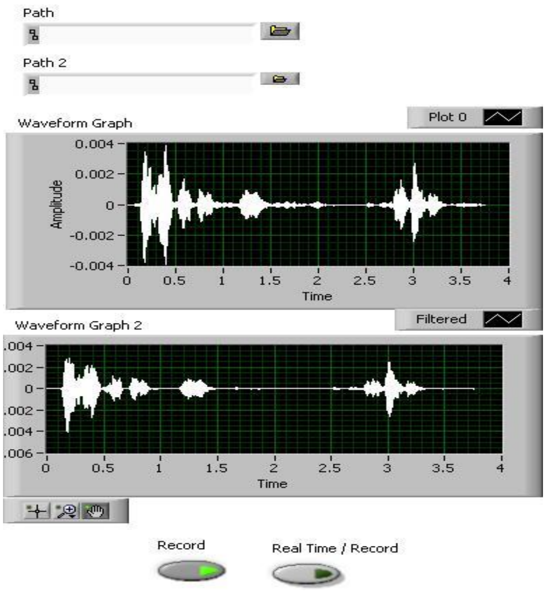

Figure 14: Front Panel for LabVIEW analysis

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