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Embedded Stethoscope for Heart Sounds

Ashish Harsola
Department of Electronics and Telecommunication Engineering, Fr. C. Rodrigues Institute of Technology, Vashi, Navi Mumbai, Maharashtra, India

Abstract

In India significant percentage of the people who die due to cardiovascular diseases belong to rural part. The major reasons are lack of awareness, lifestyle, and the cost factor. While the first two reasons are more applicable in urban India, the third is a pain point for rural areas where there are no cost-effective ways available for an early diagnosis of heart diseases. There are different tests and investigations used to diagnose heart disease. The tests doctor chooses depending upon risk of heart disease, history of heart problems and the symptoms one might have but the initial diagnosis can be done using the stethoscope used for auscultation.For many years healthcare professionals would listen quietly to patients internal organs so they could diagnose from specific sounds of these organs. But it requires lot of expertise for such diagnosis, which is not available in the rural part. The objective is to develop a Digital Stethoscope for early initial diagnosis of cardiac disorders without any high end test which the patients can be referred to, if required. The proposed design consists of a Peripheral Interface Controller (PIC) based system which consists of following stages: Front end pick-up circuitry, PIC18F4550 controller, graphic LCD display or high resolution TFT display, a memory device, USB and Bluetooth connectivity. Recorded data on memory device helps professionals to analyze later on at far distances. Bluetooth facilitates professionals to use portable devices along with its Bluetooth connectivity to capture these transmitted recordings and then analyzing these waveforms in time and frequency domain by using software such as LabVIEW.

Keywords

Auscultation, Heart sounds, Digital stethoscope, PIC 18Ff4550.

1. Introduction

Cardiac auscultation is one of the most useful investigative tools that the physician can use at the bedside to detect alterations in cardiovascular anatomy and physiology. Typically, heart sounds and murmurs are of relatively low intensity and are band limited to about 10–1000 Hz. Meanwhile, Speech signal is perceptible to the human hearing. Therefore, auscultation with an acoustic stethoscope is quite difficult. Only a small proportion of cardiovascular sound energy is audible by the human ear, see Figure 1, The problem with acoustic stethoscopes is that the sound level is low, making diagnosis more difficult. So auscultation is a highly variable tool as it depends upon how the readings are interpreted by the experts.

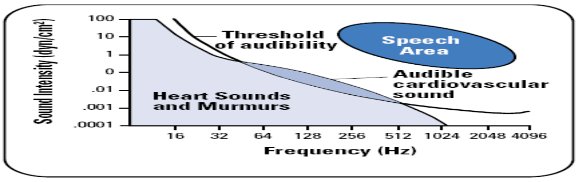

Figure 2.1: Relationship between the range of sounds produced in the heart and the human threshold of audibility

The objective is to develop a PIC based Digital Stethoscope to capture heart sounds and diagnose them with the help of display and analytic tools. The proposed design [1] [2] of the system includes: Front-end pickup circuitry, PIC18F4550 controller, memory device, graphic LCD or high resolution TFT display and a Bluetooth connectivity tool. The objective is to develop a technique which makes a clear distinction between normal heart sounds and heart murmurs. The device would also provide a graphical plot of the captured sounds to make distinction by referring to the approximate waveforms for normal heart sounds and various types of murmurs. The data can be analyzed by using analytic tool such as LabVIEW.

2. Problem Definition

Heart patients are needed to be monitored continuously so that diagnosis can be made correctly and preventive measures can be taken. The current systems available for auscultation are mainly consisting of diagnosis on the basis of hearing heart sound thus, it is difficult to differentiate between Heart sound and suspicious murmur. Available digital stethoscope models do not provide graphical analysis of the sound which is necessary to examine frequency components in some cases. The system need to be compact and wireless providing connectivity with portable devices, so that data can be analyzed on them. The diagnosis systems available in the market are costly.

3. 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 [3]. The sound heard during auscultation are called the first (S1) and the second (S2) heart sounds respectively, shown in Figure 1. The first two heart sounds (S1 and S2) are "normal" heart sounds that should be detectable in most patients. The S1 sound represents the near-simultaneous closure of the mitral and tricuspid valves, after blood has returned from the body and lungs. This is the start of systole. The S2 sound represents the near-simultaneous closure of the aortic and pulmonary valves as blood exits the heart to the body and lungs. This is the end of systole and the beginning of diastole.

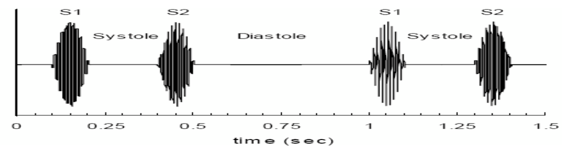

Figure 1: Heart sound of a normal person

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 100Hz-600Hz [4].

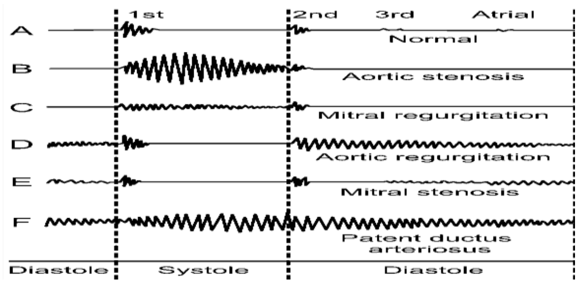

Figure 3: Normal and abnormal heart sounds

4. Proposed System

Current problems ask for an advance and cost effective design. A proposed system provides facility of analysis of heart sounds based on hearing as well as graphical analysis of different frequency components. A signal picked up from patient is amplified, filtered and digitalized for further processing. A digital data is displayed on graphic display and can be stored on memory device for future reference. System allows user to send the data on portable devices such as laptops or mobiles for analysis using dedicated applications.

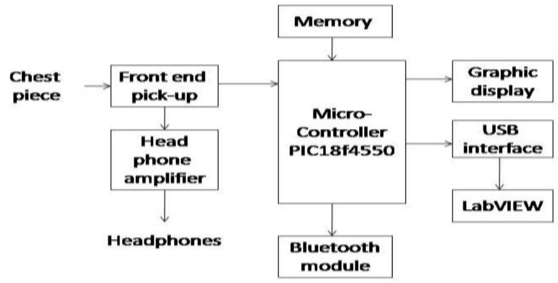

Figure 4: Block diagram of the system

The proposed system [1] [2] consists of:

4.1 Front-End Pickup Circuitry

The front-end pickup circuitry [1] [2] is as shown in Fig. 5.

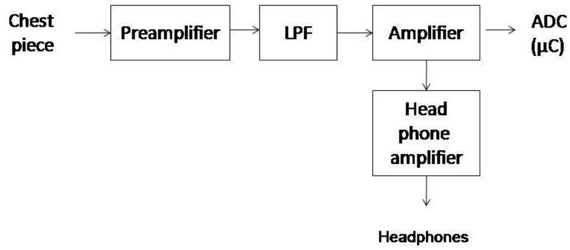

Figure 5: Front end circuits

Chest piece picks up the heart sounds. This is then fed to the Pre-amplifier circuit to provide sufficient gain and hum rejection. The amplified signal is then fed to the 3^{rd} order LPF filter with a cut-off of 800Hz to capture only desired signal. The amplifier output is also fed to headphone amplifier to get audible sounds on the head phones. Final amplifier circuit provides adjustable gain to get required signal level for the on chip ADC of PIC18f4550.

4.2 Microcontroller

PIC18F4550 is the central part of the system which holds the entire system together.
Some features are :

- Program Memory 32KB (Flash)
- CPU speed 12 MIPS
- RAM Bytes 2048
- On chip ADC - 13 channel, 10 bit
- Full speed USB 2.0

4.3 Display

Graphic LCD displays the data captured from front end into waveform. Data is converted from analog to digital form and send it to graphical display.

JHD12864E model is chosen because of low cost over other parallel displays to make system cost effective.

4.4 Memory Device

The data is recorded on the memory device for later analysis. The memory device can be a serial EEPROM or a micro SD card. AT24C1024 EEPROM is used as storage device.

5. Implementation

Following circuits has been tested using simulation software.

5.1. Front end pick-up

Proteus simulation of front end pick-up circuits has been done. A preamplifier has been designed with gain of 31. A LPF is 3rd order Butterworth filter with cutoff frequency of 800 Hz. A PCB for preamplifier and LPF has been made and tested. A layout for final amplifier and headphone amplifier has been done.

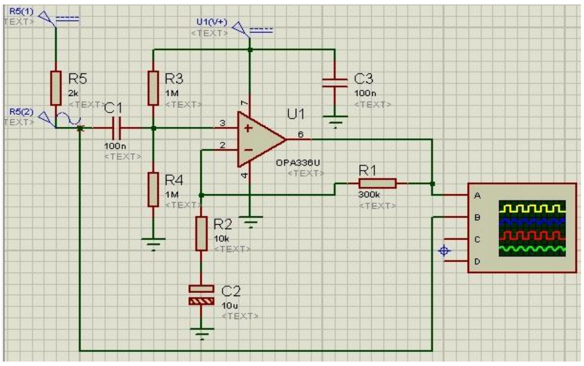

Figure 6: Proteus schematic for Preamplifier

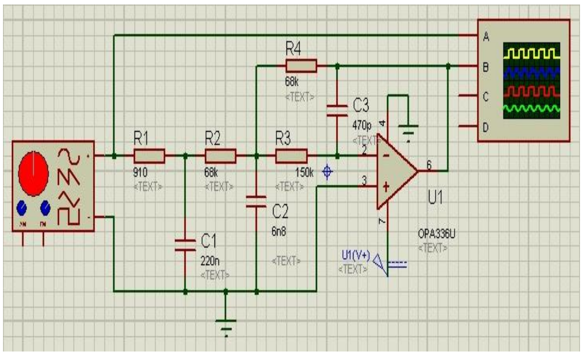

Figure 7: Proteus schematic for Preamplifier for LPF

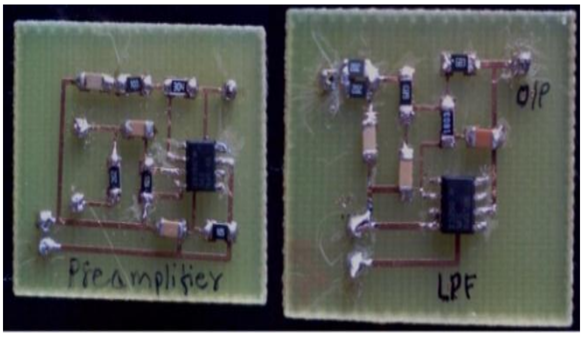

Figure 8: Soldered PCB for preamplifier and filter

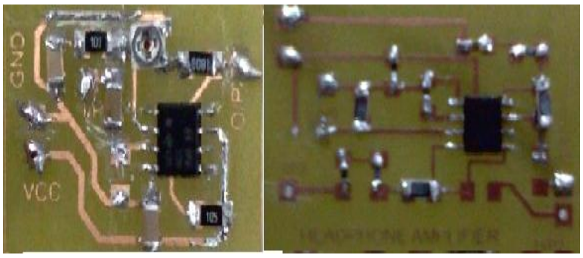

Figure 9: Soldered PCB for final amplifier and headphone amplifier

5.2 Graphic LCD Interface

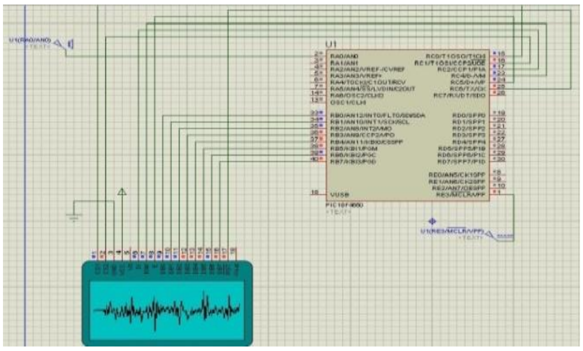

Figure 10: Proteus schematic for Preamplifier for GLCD interface

The JHD 128x64 parallel GLCD available with proteus has been interfaced with PIC18f4550. The simulation is tested with sine wave as input from the internal function generator and also recorded wave files (.wav) for different heart sounds.

5.3 Memory Interface

An EEPROM AT24C1024 available with proteus has been interfaced with PIC18f4550 using the I2C protocol. The memory will help to record the heart sounds for future analysis.

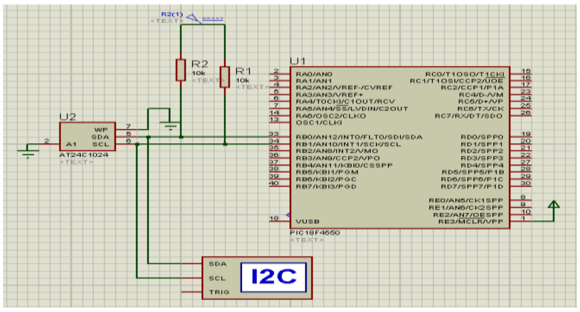

Figure 11: Proteus schematic for Preamplifier for memory interface

6. Result

Simulation results achieved are as follows:

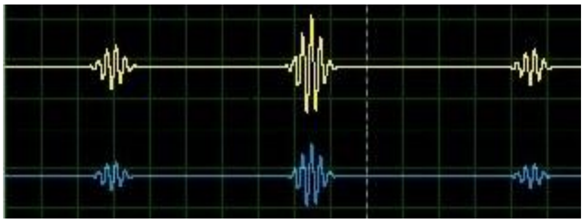

Figure 12: Proteus simulation output for preamplifier

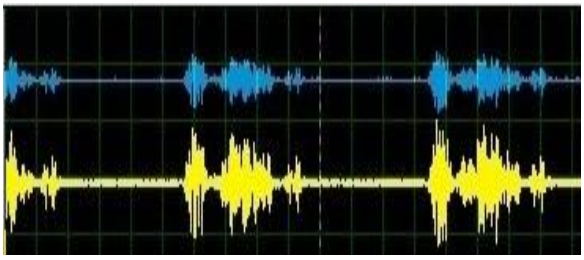

Figure 13: Proteus simulation output for LPF

Figure 14: preamplifier and LPF output on DSO

Practically preamplifier provides gain of 28 and LPF has transition band 1.7 KHz with stop band attenuation of 15dB. The simulation output of the graphic LCD with heart sounds given as input in .wav format is compared with the same wave file given to Sony Forge software. As can be seen there is appreciable amount of similarity in the simulated and the actual waveforms.

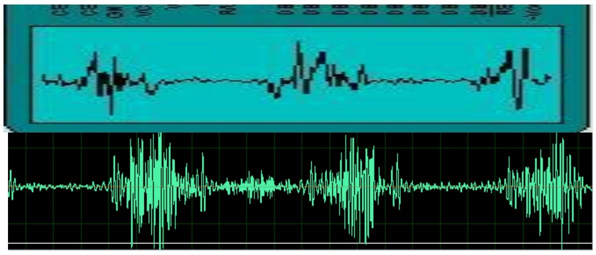

Figure 15: Aortic Stenosis

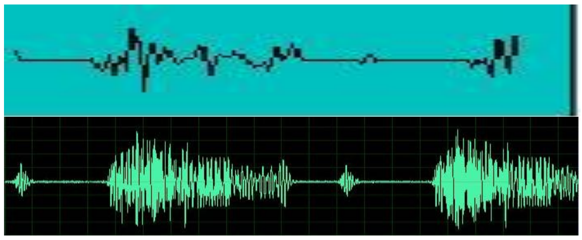

Figure 16: Aortic Regurgitation

Figure 17: Patent duct stenosis

LabView Analysis:
The LabVIEW analysis is done on the heart sounds via the sound card of the Laptop. The signal is acquired through the modified chest piece and than passed through a Low pass filter (0-600Hz) to band limit the signal and plotted on the waveform graph. Also spectral measurement is done for the received signal.

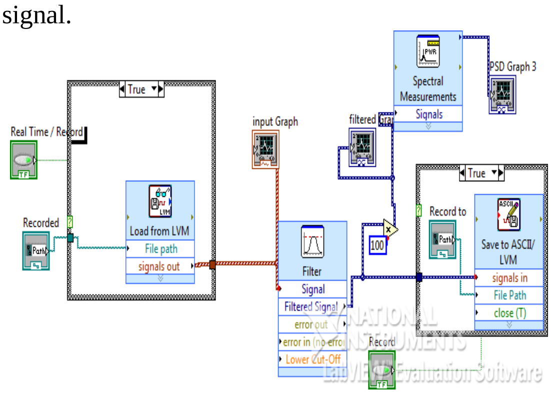

Figure 18: LabVIEW Block Diagram

7. Conclusion and Future Work

The preamplifier and low pass filter which are part of Front end circuit have been tested using OPA 335 with input from the chest piece with embedded microphone. The results are encouraging and the work is in progress. The Graphic LCD interface with PIC18F2550 is completed and five abnormal heart sound waveforms have been displayed successfully. The Front end circuit will be tested with the actual heart sound after making the PCB. Once all the modules are ready than the whole system will be assembled and tested. The obtained signal is processed using LabVIEW and the time and frequency domain waveform are displayed on the PC. Heart rate calculation using LabVIEW will be carried out. Bluetooth module has to be interfaced to make Graphic LCD wirelessly connected to stethoscope.

Acknowledgment

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Ashish Harsola was born in Khetia (M.P), 1979. He receivedhis M.Tech degree in Electronics Engineering from V.J.T.I, Mumbai in 2011. Currently, he is working as Asst. Professor with Fr.C.R.I.T, Vashi. His research interests include embedded systems and Digital communication. He is life member of ISTE and has total of five papers in national and international conferences to his credit.