Design and Implementation of a PC based Electronic Stethoscope

Md. Shakhayat Kabir

Abstract— This paper based on an electronic stethoscope to convert acoustic sound waves to electrical signals which can be amplified and processed for further analysis. The tool was equipped with an electronic stethoscope specifically designed to improve the quality of the auscultation. The electronic hardware was enriched by a software platform to manage auscultations and to provide an assisted diagnosis. Experimental results confirm the accuracy both of the sound detection and for the further analysis of a patient data.

Index Terms— Electronics, Piezo Transducer, PC interface, Sound record, MATLAB, Code, Amplifier, Filter.

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1. INTRODUCTION

Realizing the need of flawless diagnosis of diseases, medical science has adapted various engineering ideas into its structure. Advanced technologies are used now a days to identify or detect the very root of complex diseases. We are motivated to work with a very basic equipment, used vastly on daily life diagnosis by the doctors. We developed an electronic stethoscope which is accompanied by a PC interface that will help us to make further analysis of the patient data.

The common stethoscopes are mechanical devices. We developed a piezoelectric element based electronic stethoscope. The piezoelectric element can sense the vibrations even accurately than the normal chest pieces. This provides a considerably noiseless sound for its users. The signals is converted electrically and amplified towards the user's earphones.

A PC interface is attached, which allows the user to transfer the patient data to a PC and generate wave shapes. The wave shapes can be analyzed and more specific conclusions can be made about a patient.

The piezoelectric transducers work on the principle of piezoelectric effect. When mechanical stress or forces are applied to some materials along certain planes, they produce electric voltage. This electric voltage can be measured easily by the voltage measuring instruments, which can be used to measure the stress or force.

The physical quantities like stress and force cannot be measured directly. In such cases the material exhibiting piezoelectric transducers can be used. The stress or the force that has to be measured is applied along certain planes to these materials. The voltage output obtained from these materials due to piezoelectric effect is proportional to the applied stress or force. The output voltage can be calibrated against the applied stress or the force so that the measured value of the output voltage

directly gives the value of the applied stress or force. In fact the scale can be marked directly in terms of stress or force to give the values directly.

The voltage output obtained from the materials due to piezoelectric effect is very small and it has high impedance. To measure the output some amplifiers, auxiliary circuit and the connecting cables are required [2].

2. BACKGROUND AND MOTIVATION

Stethoscope is medical equipment which uses to hear the internal sound of the human body. It is consists of earplugs, binaural pieces, flexible tubing, a stem, and a chest piece. It works through mechanical process. Its diaphragms capture the sound and pass the sound through the earplugs. This sound is very low. Sometimes it is used for listening internal sound of the machine. But it is vastly used in medical science. The word stethoscope is derived from the two Greek words, stethos (chest) and scopos (examination). Apart from listening to the heart and chest sounds, it is also used to hear bowel sounds and blood flow noises in arteries and veins. As it is used to hear internal body sound which help the doctor to identify the disease. If their initial examine is wrong then the further examine may also be wrong. That's why stethoscope is important equipment in the medical science. [1]

In 1851, Irish physician Arthur Leared invented a binaural stethoscope and, in 1852, George Philip Cammann perfected the design of the stethoscope instrument (that used both ears) for commercial production, which has become the standard ever since. Cammann also wrote a major treatise on diagnosis by auscultation, which the refined binaural stethoscope made possible. By 1873, there were descriptions of a differential stethoscope that could connect to slightly different locations to create a slight stereo effect, though this did not become a standard tool in clinical practice [6].

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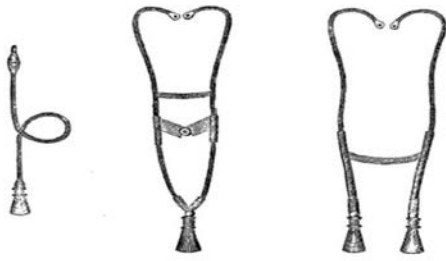
Fig 1: Early flexible tube stethoscopes. Golding Bird's instrument is on the left. The instrument on the right is the stethophone [6]

Acoustic stethoscopes are familiar to most people, and operate on the transmission of sound from the chest piece, via air-filled hollow tubes, to the listener's ears. The chestpiece usually consists of two sides that can be placed against the patient for sensing sound: a diaphragm (plastic disc) or bell (hollow cup). If the diaphragm is placed on the patient, body sounds vibrate the diaphragm, creating acoustic pressure waves which travel up the tubing to the listener's ears. If the bell is placed on the patient, the vibrations of the skin directly produce acoustic pressure waves traveling up to the listener's ears. The bell transmits low frequency sounds, while the diaphragm transmits higher frequency sounds. This two-sided stethoscope was invented by Rappaport and Sprague in the early part of the 20th century [6].

Fig 2: Traditional Stethoscope that is used by the doctor for diagnosis.

Today the necessity of electronic stethoscope is very much essential over the traditional cheap and cheerful stethoscope. In case of the traditional stethoscope we are able to hear the sound in quite environment. But in noisy place it is difficult to hear the sound as its sound level is modest, particularly at low frequencies. That's why the sound often electronic stethoscope is heard through headphone.

This electronic stethoscope has plenty of gain where the user can adjust volume level to suit. The user can also use switchable filtering to cut or boost a particular band of frequencies. Also, it can be connected to headphones or loudspeakers in which case more than one person can hear the sounds. The sound can be recorded and the waveform can be displayed on a computer screen.

3. OBJECTIVES

The main objective of this project is to design and construct an electronic stethoscope to convert acoustic sound waves to electrical signals which can be amplified and processed for further analysis.

The specific objectives of this project are:
- Conversion of acoustic sound waves to electrical signals.
- Pre-processing of auscultation signals, involving removal of interference noise and separation of respiratory noises, and amplification of the signals.
- Transmitting the heart sounds signal to a personal computer using a graphical user interface for analysis and to build-up the data-base for replay, demonstration or consultation purposes.
- Calculation and display of heart beat rate.

4. SOFTWARE INTERFACING

We have mainly used two software for our project. First one is MATLAB and the other one is Proteus. In MATLAB, we write the code to observe the frequency response of the patient heart beat sound. By using proteus software we design and also simulate our circuit.

4.1. MATLAB Software

MATLAB is widely used in all areas of applied mathematics, in education and research at universities, and in the industry. MATLAB stands for Matrix Laboratory and the software is built up around vectors and matrices. MATLAB has powerful graphic tools and can produce nice pictures in both 2D and 3D. It is also a programming language, and is one of the easiest programming languages for writing mathematical programs. MATLAB also has some tool boxes useful for signal processing, image processing, optimization, etc.

Features of MATLAB

- It debugs the executable logic by watching program flow with the built-in.
- Simulator or in real time with in-circuit emulators or in-circuit debuggers.
- It makes timing measurements with the simulator or emulator.
- It views variables in watch windows.

4.2. Proteus Software

Proteus software is renowned to all for software simulation. Proteus is the software of "LABCENTER" Electronics. This software has a library. From this library any components can be include in the circuit for simulation. It has thousands of components that use in real life and for a certain period of time library can be updated by internet. It is the professional software for embedded designers. It helps a designer to complete the work.

Features of Proteus

- Requirement definition

- Functional specification
- Design
- Detailed specification
- Testing
- Documentation
- User testing
- Ongoing support

Working with Proteus

The Proteus is the simple and most essential software with latest technology for circuit implementation and simulation. It has ISIS which is for circuit design and simulation and ARES which is for PCB designing. Starting the software there is a library for including the components. Including necessary components it can be simulate after building the circuit. It is necessary to give corresponding information to the components for its necessary work

5. BLOCK DIAGRAM

We can describe the whole operation of the circuit briefly by using some block diagrams. A block diagram is a graphical method used to explain the concept of a system without the need to understand the individual components within that system. This type of diagram might be used in a variety of industries to illustrate and educate individuals about how a system operates, either in part or in its entirety. Block diagrams usually will have a logical, methodical flow from beginning to end. [10]

5.1 Block Diagram of the proposed Design

First, the heart beat sound is taken by the chest piece diaphragm. Then the sound is sensed by the piezo electric transducer which converts the mechanical signal to electrical signal. Since the signal is very low that's why the signal is amplified with a very high gain amplifier in different stage. Then a frequency switcher is used by which we can observe
the frequency response up to a certain frequency level (from 63Hz to 4 kHz). At the output stage a power amplifier is used by which the output signal can be drive by an earphone.
In another output an ADC circuit is used which convert the analog signal to digital signal. Then the signal connected to PC input through cable and we can observe the frequency response in PC by coding in MATLAB.
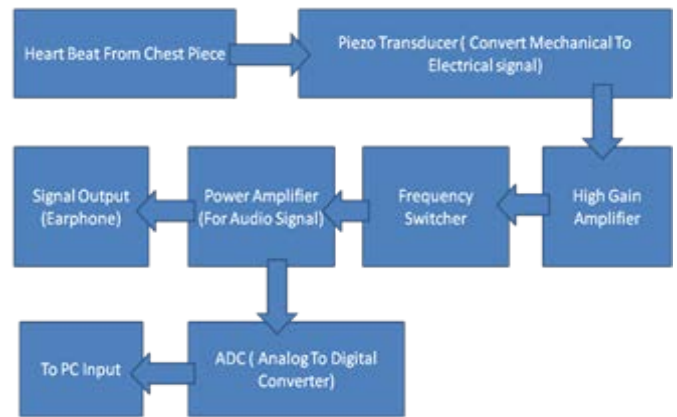

Fig 3: Working Principle of Electronic Stethoscope.

6. PROPOSED CIRCUIT DESIGN

The Electronic Stethoscope circuit is based on two low cost ICs- a TL074 quad op amp and a LM386 power amplifier. The op amp is used for amplification and filtering of the signal that takes using piezo element in the chest piece. The power amplifier is used for driving the headphones.

The piezo element signal is applied in the input connector (CON1) and pass through a 100nf capacitor to op amp IC1c. The 33pf capacitor and 10 ohm resistance are used
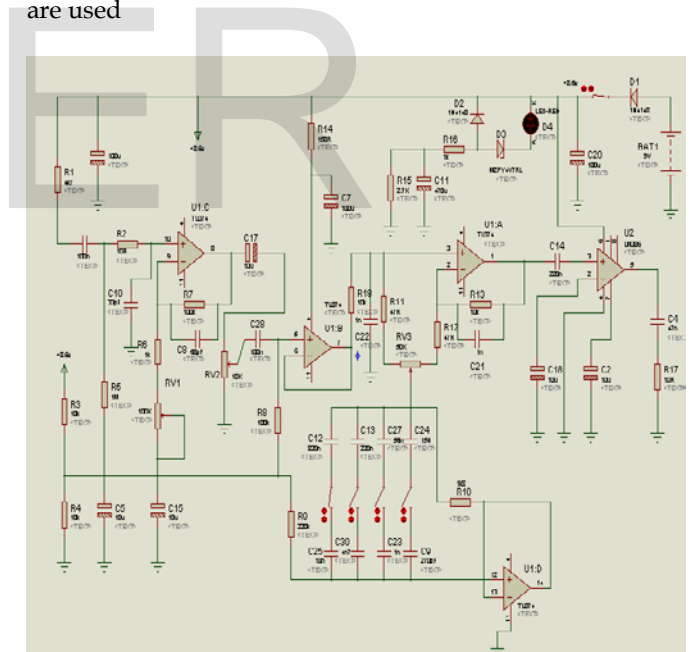

Fig 4: Circuit design of Electronic Stethoscope in Proteus.

to attenuate high frequencies and reducing the possibility of picking up radio signals. The IC1c is biased at +4.3V via 1M ohm resistor connected to the 10k ohm voltage divider resistors across the 8.6V voltage supply. The 1M ohm resistor sets the amplifier input impedance.

The IC1c op amp is connected as a non-inverting amplifier with a gain that can be varied by using a trimpot VR3 (100k ohm). When the trimpot is set to minimum resistance we can get high gain and when the trimpot is set to maximum resistance we can get low gain

amplifier. IC1c is coupled to the volume control potentiometer VR1 (10k ohm) via a 10uf capacitor. The output of the volume controller is connected to the IC1b which is a unity gain buffer. Output of the IC1b drives the equalizer stage consisting of op amp 1C1a and IC1d.

The op amp 1C1a and IC1d form a single band equalizer which cut or boost the signal in a defined frequency band. Potentiometer VR2 (50k ohm) sets the amount of signal to be cut or boost. The VR2 is connected to IC1a via a 47 ohm resistor. When VR2 is rotated to its boost setting the LC network is connected directly to the inverting input of the op amp via another 47 ohm resistor. At the resonant frequency, the low impedance of the LC network reduces the feedback and the gain of IC1a will increase.

After the equalizer stage, the signal is fed to IC2 (power amplifier) through a 220nf capacitor. The power amplifier can provide about 500mw into 8 ohm with a 9V supply. When using stereo headphones, the power is about 250mw more than enough to provide sufficient listening volume. Power amp IC2 drives the output through a 470uf capacitor and a 10 ohm resistor and 47nf capacitor which helps prevent amplifier instability.

A 9V battery supply is connected through a diode D1 providing protection against a reverse polarity connection. A schottky diode is used because of its low forward voltage loss (about 0.3V). A led is used in the circuit which has two functions. First one is to show power "on" and the second one is to show the battery condition. When the power is applied, current for the led flows through the 4.7V zener diode, the 1K ohm resistor and discharged through 470uf capacitor. The 9V fresh battery provides 8.7V at the anode of led. This voltage is reduced by about 1.8V by led and 4.7V by the zener diode. The rest 2.2V reduce across the 1K ohm resistor. In that case the led glows brightly. At the lower battery voltage, there is less voltage loss across the 1k ohm resistor, so the led dims. As the 470uf capacitor charge up, the led current is reduced by much lower level set by the 2.7k ohm resistor. This indicates that the electronic stethoscope is switched on without wasting significant power. When the switch is off, diode discharges the 470uf capacitor so that the circuit is again ready to indicate the battery level when it is turned back on.

7. SYSTEM SPECIFICATION

For the input signal, we have take a piezoelectric transducer based electronic stethoscope which convert the mechanical signal to electrical signal. The signal is operated in low voltage normally in mV range and also the frequency is low.

For the output signal, we have got an amplified signal. The gain of the amplifier is varying from 0 to 60. The input signal is amplified enough to drive the earphone. The power amplifier can provide about 500mw into 8 ohm with a 9V supply. When using stereo headphones, the power is about 250mw more than enough to provide sufficient listening volume.

8. SIMULATION AND RESULT ANALYSIS

In the results part, we simulate our circuit in different way. After analysis all the results that we get during simulation to ensure that our project has been run successfully. We simulate our circuit in 3 ways which have discussed below.

- ➢ In Proteus
- ➢ In Oscilloscope
- ➢ In MATLAB

Table (Simulation Result)

Simulation	Input Voltage (V)	Output Voltage (V)	Overall Gain	Frequency (F)
Proteus	1V	3.3V	3.3	30Hz
Oscilloscope	5mv	200mv	40	30Hz

8.1 Simulation Results in Proteus

We have design our circuit in proteus 7.8 SP2. For simulation in proteus, we insert digital oscilloscope from the proteus library in the input and output of our design.

In the input we set 1V (peak) AC wave signal and the frequency is set to 30Hz because the stethoscope operate at very low frequency.
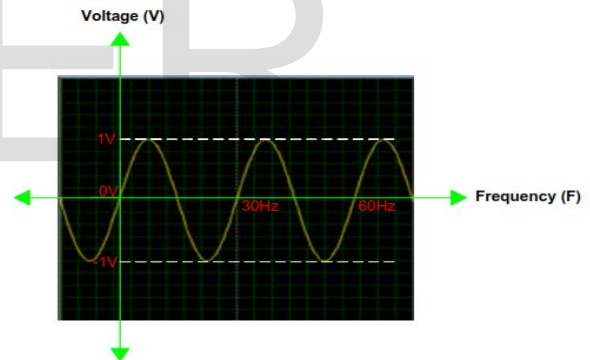

Fig 5: Input wave shape in proteus.

At the output of our circuit we get 3.3V (peak) AC wave signal. So, the output of the signal is amplified more than three times of the input signal.
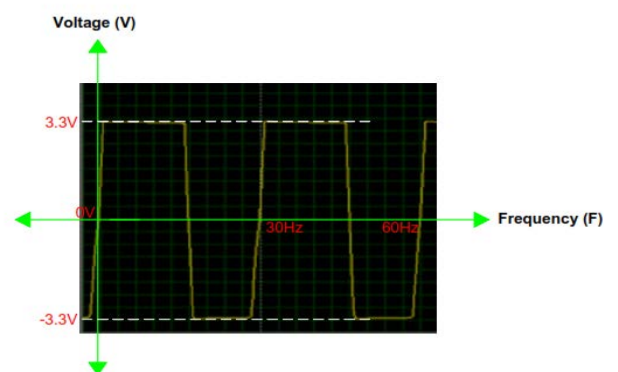

Fig 6: Output wave shape in proteus.

8.2 Simulation Results in Oscilloscope

We have also simulated our circuit using oscilloscope. For the simulation, we using a signal generator to give input in the circuit and through oscilloscope probe we can see the output in the oscilloscope.

For the input, we give 5mV (peak) AC sinusoidal wave from the signal generator and the frequency is selected to 30Hz.
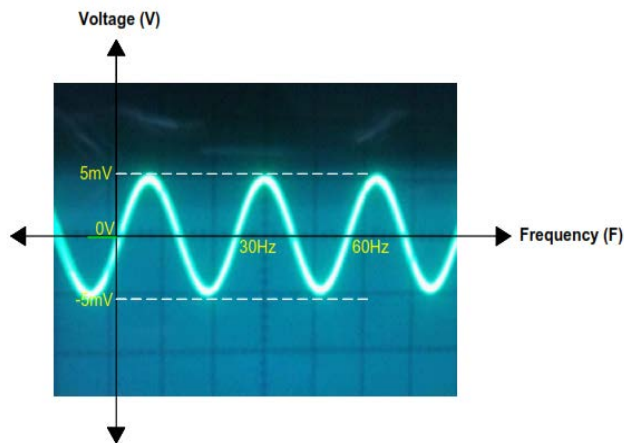

Fig 7: Input wave shape in oscilloscope.

From the output, we get 200mV (peak) sinusoidal wave of same frequency range. The output signal is amplified 40 times than the input signal. So, the gain of the circuit is 40. We can vary the gain of our circuit by varying the potentiometer.
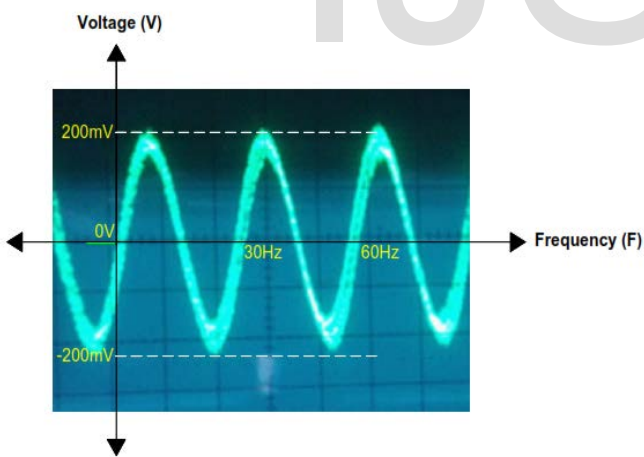

Fig 8: Output wave shape oscilloscope.

8.3 Simulation Results in MATLAB

For the simulation in MATLAB, we write the code in MATLAB command window. When we run the code, first it displays "Start measuring" in the command window. Then, it records the patient heart beat sound for 10 seconds. After that, it displays "End of taking measurement" in the command window. We declare the variable y for the function audiorecorder which records the audio sound. After 10 seconds, the audio recording is

blocked and the resultant audio data is stored in the variable y. We can also able to play the recorded heart sound. Then, we store the recorded data in double precision array. For the observation of wave shape, we declare another variable x. In variable x, we use a function getaudiodata to get the previously recorded audio data for y which is now store in variable x. Then using the plot command, we can observe the wave shape of the recorded heart beat sound.

MATLAB Code

```
% Record the heart-beat for 10 seconds
%--------------------------------------
y = audiorecorder;
disp('Start measuring')
record blocking(y, 10);
disp('End of taking measurement');
%Play back the recording
%----------------------
play(y);
%Store data in double-precision array
%------------------------------------
x = getaudiodata(y);
% Plot the waveform
%------------------
plot(x);
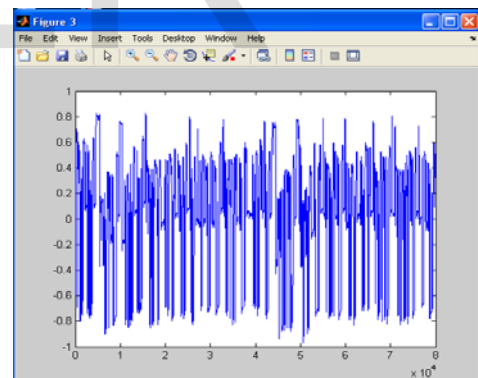```

Fig 9: MATLAB code.



Fig 10: Wave shape of the heart beat sound recorded in MATLAB for 10 seconds.

## 9.  DESIGN PROTOTYPE

We have designed the PCB layout after implementing the whole circuit on the bread board to check whether it works properly or not.
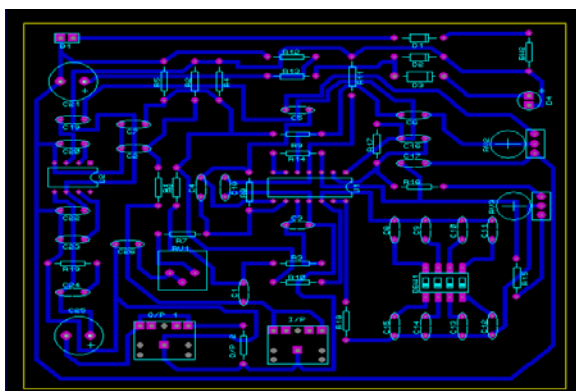
### 9.1 PCB Design



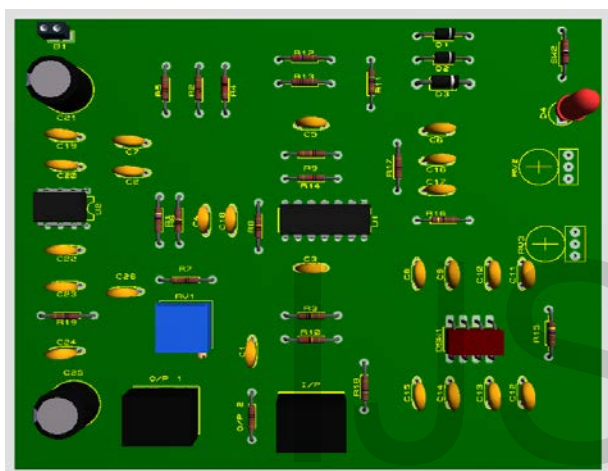Fig 11: PCB Design using Proteus 7.8SP2.



Fig 12: 3D visualization of component using Proteus 7.8SP2.
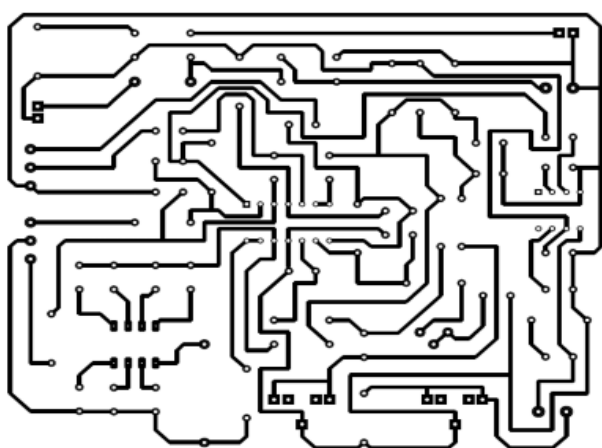


Fig 13: Bottom layout (Mirror Image) of PCB.

### 9.2 Physical Construction



Fig 14: Implementation of chest piece for auscultation.



Fig 15: Implementation of amplifier circuit with features in PCB board.



Fig 16: PC interface of Electronic Stethoscope.

## 10.CONCLUSIONS

For better and more accurate diagnosis and also further analysis of a patient data, a pc based electronic stethoscope will be an alternative way in compare to traditional stethoscope that are available in market. It's a low cost device which overcomes the auscultation problem by increasing heart beat sound to a certain level. It creates more opportunities to work on this project for students to improve its performances. So it is expected that more works will be done on relevant project in near future.

## 11.FUTURE WORK

Numerous improvements can be made in the future to fully satisfy the requirements and improve the final prototype. By using microcontroller, we can integrate the size of our circuit. We can also improve in the prototypes functionality. Another modification can be done by some form of wireless technology into the prototype such as Bluetooth microphones attached to the stethoscope heads, would significantly improve the functionality of our prototype by eliminating the wires which currently connect the microphones to the main circuitry.

## ACKNOWLEDGEMENT

**Md. Shakhayat Kabir** received the B.Sc. degree in Electrical and Electronic Engineering from American International University-Bangladesh, Dhaka, Bangladesh in 2014.

His current research interests are in Power System Protection, Control Systems, Industrial Engineering, Renewable energy, Wind power, Power Electronics and Microcontroller.

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