Department of Electronic and Telecommunication Engineering

University of Moratuwa

EN2090 – Laboratory Practice - II

Preliminary Design

Electronic Stethoscope

Group Number: 28

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Abstract

Medical diagnosis is generally considered as a multifaceted factual approach (to solve a disease matrix) in which several observational and analytical aspects play virtually and interactively in order to obtain the required sense of curing the patient. Further, it is obvious to state that auscultation, which could be simply identified as listening to the sounds produced by the (human) body, plays a major role in the above process further; it is known that the Stethoscope is the key element to achieve the preferable outcome of this auscultation.

Stethoscopes are optimally utilized for the purposes of medical requirements especially in detecting normal and/or abnormal respiratory, cardiac, arterial, fetal, venous, intestinal and uterine sounds of humans as well as of animals. In addition, they are also used for achieving various intentions in mechanics and exterminators. In this project, we propose to build an electronic stethoscope which could optimally replace the general functions of traditional stethoscope that basically consists of a rubber tube and a disk-shaped diaphragm.

Mission Profile

In general, it is highly accepted that the auscultation through traditional stethoscopes profoundly requires substantial clinical experiences and better listening skills. In relation, they are fundamentally aimed for medical utilization in diagnosis. Even though this requirement is essential, external noises inside hospitals may lead to produce weak sound signals through stethoscopes and thus the sounds are considerably inaudible. Thus, this may lead to miss any important diagnosis by the listener.

In addition, sometimes, the body itself produces much weak sound signals in diseases such as in early stage of cardiac dysfunction in which traditional stethoscopes could less be helpful in diagnosis process. Therefore, it is required to approach these particular problems with a different perspective; which we propose as “electronic stethoscope”. Electronic stethoscopes could overcome the low sound signals by electronically amplifying the body signals after converting acoustic signals into electrical signals. Further, low pass filtering in electronic stethoscopes is intended to reduce the background noises if any occurred.

Intended Quality Control and Safety

Safety precautions will primarily include:

- Precautions against infectious risks
    - Only the stethoscope head is intended to be disinfected (with Isopropyl Alcohol solution)
    - Do not recommend using hand sanitizers as a cleaning agent as it will damage the electronic components in the device
    - It is recommended to not to store and/or use the device with contact to extreme heat/ cold/ solvents or oils
    - We intend to manipulate the specifications of the device so that stethoscope head could be removed in order for cleaning purposes
- Precautions against electromagnetic fields/ sharp edges/ electrical shock/ incorrect results
- The quality control measurements and compliance measurements will follow the guidelines represented in Littmann Stethoscope Model 3200 via https://multimedia.3m.com/mws/media/594115O/3m-littmann-electronic-stethoscope-model-3200-user-manual.pdf

Requirements

(Verification and Validation will not be discussed in the Preliminary design)

We propose to design an electronic stethoscope which could be utilized as an optimal alternative for a traditional stethoscope as it amplifies the acoustic signals to a considerable gain level; hence nearly no sound is missed. Therefore, this device could be even used by less experienced practitioners in the medical field.

- The entire design is intended to be in analog domain
- The device is intended to operate up to 20Hz in low frequency
- The (low pass) filtering of the device is intended to have at least 1kHz cut-off frequency
- The power requirement of the device is intended to have at most 9V DC
- The device is intended to use a stethoscope head and an electric mic for sensor purposes
- Volume control is intended to be applied
- Safety precautions for hearing are intended to implement as necessary and suitable
- The output of the device shall be obtained in acoustically and visually (Ex. through LED blinking corresponding to heart beat)
- Further improvements such as visualizing output signals on (android) screen is intended to be included as time availability

Design Innovation

As per the above requirements, we have concluded that the device will fundamentally in need of a Sensor stage, a Pre-amplifier, a Low pass filter (butter-worth), a Power Amplifier and an output stage to have the basic intended functionality. So the basic Stages that the device will go through would be:

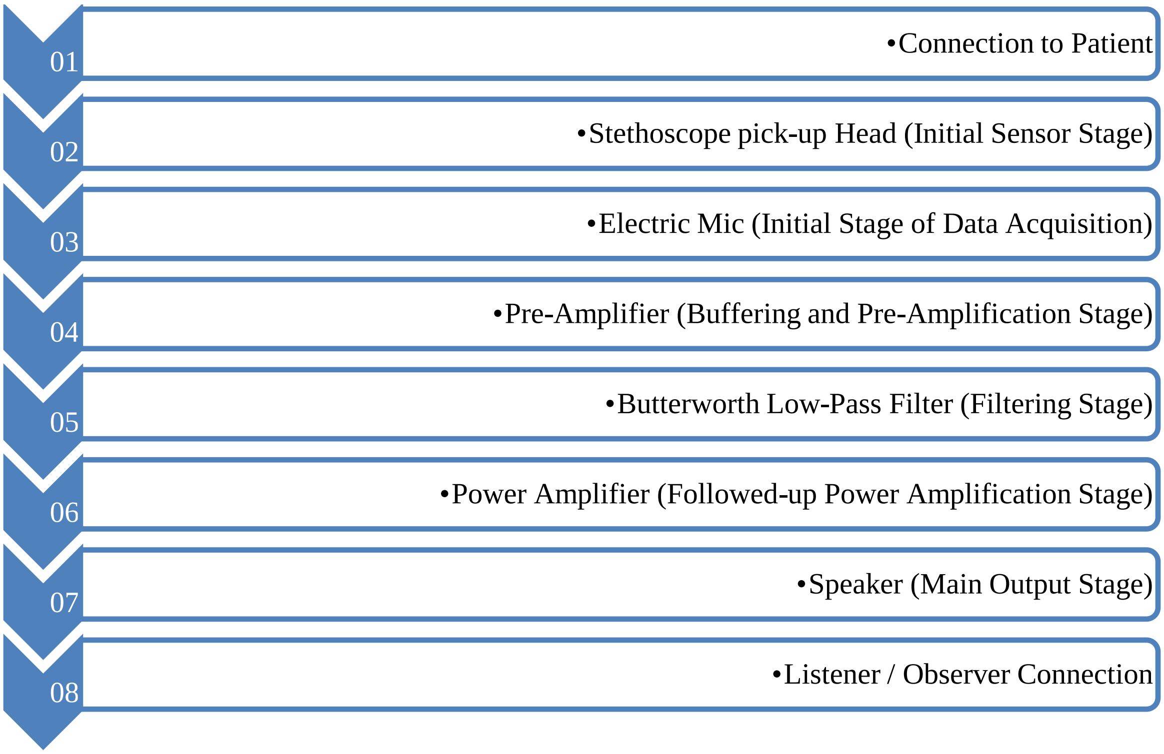

Figure: Basic Implementation of Functional Flow of the proposed device

(This diagram was introduced in the Project Proposal)

Project Breakdown Structure and Subsystem Design

(Software Design will be intended to be discussed in a later iteration)

The whole Project is profoundly categorized under several main parts and disseminated within the group members:

- Electronic schematic diagrams
- PCB Layouts
- Enclosure Design

- Signal Processing
- Simulations
- Suggestions, Testing and Analysis
- Documentation and Publications

Each subsystem mentioned in the Design Innovation is intended to have various possible design/electronic component options and thus, we intend to explore these design ideas and measure/evaluate in response to requirement levels collaboratively.

Electronic System Design

- Basic Sensor Stage
  We have investigated that, there are several sound capturing sensor elements for basic sensor purposes such as:
  1. Piezoelectric Crystals
  2. Capacitive sensors
  3. Electret Microphone

  Among these options, we analysed that Electret microphones are more feasible us to implement since they are comparatively cheap and easy to implement on the purpose.

  Further, we intend to use a higher sensitive (high electrical response level at output when an acoustic signal input is given) and high SNR valued Electret microphone device (Preferably Electret Condenser Microphone – ECM) in order for better implementation process. In addition, we expect to use rubber pipe and a funnel for better closed system.

- Pre-Amplifier
  This is the immediate following main stage after the basic sensor stage. We have investigated that the Gain which is required and the high pass cut-off frequency are the essential factors while designing the Pre-amplifier for the circuit.
  Hence, we have found about the following options:
  1. TL072 Dual Operational Amplifier
  2. LM358 Operational Amplifier
  3. LMP7704 Operational Amplifier

  Among the above options, a selection criteria has being developed based on requirements of gain, cut-off frequency, single-supply inverting, low-noise factor, buffering requirement etc. along with the other components such as resistor values and capacitor values.

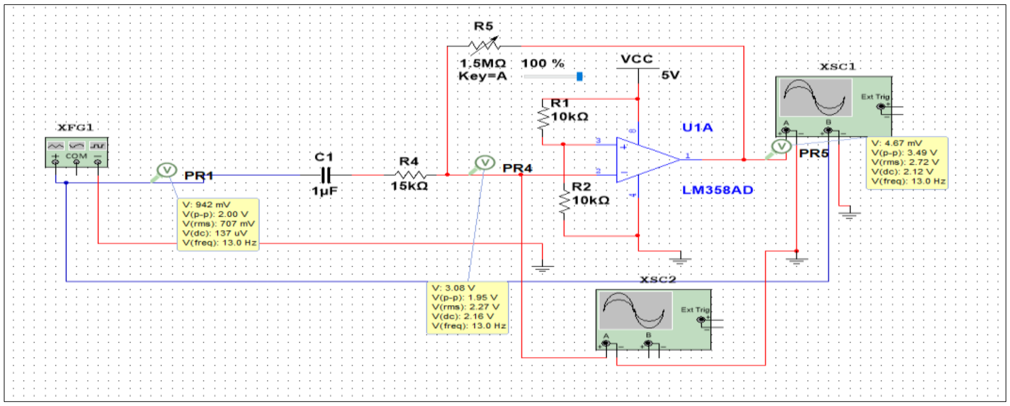

Figure: Sample Pre-Amplifier Simulation Design Using LM358 OpAmp

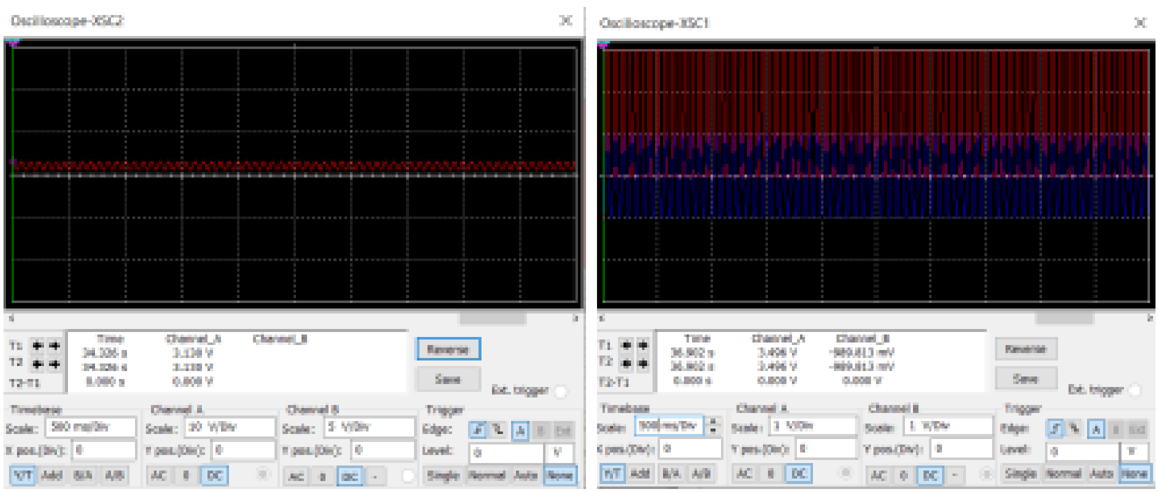

Figure: Sample Simulation Results

- Low-Pass Filter
  As we expect to have high ambient noise signal to be added to the acoustic signals, we expect to have low-pass filters in order to get better signal response from the system. As we have analysed, the medical practitioners are only concerned of the acoustic signals from the body below 1khz, we expect to have a cut-off frequency of 1khz and a cut-off frequency about 100hz to 300hz for better diagnosis purposes. We have evaluated several below options for us in regard this:
    1. TL072 low-noise, dual operational amplifier
    2. LM358 operational amplifier
    3. OP281GRU operational amplifier
    4. IC741 operational amplifier

  We expect to conduct the relevant simulations with respect to the requirements (gain, cut-off frequency sharpness, roll-off rate) in order to better select the required operational amplifier along with other analog components.

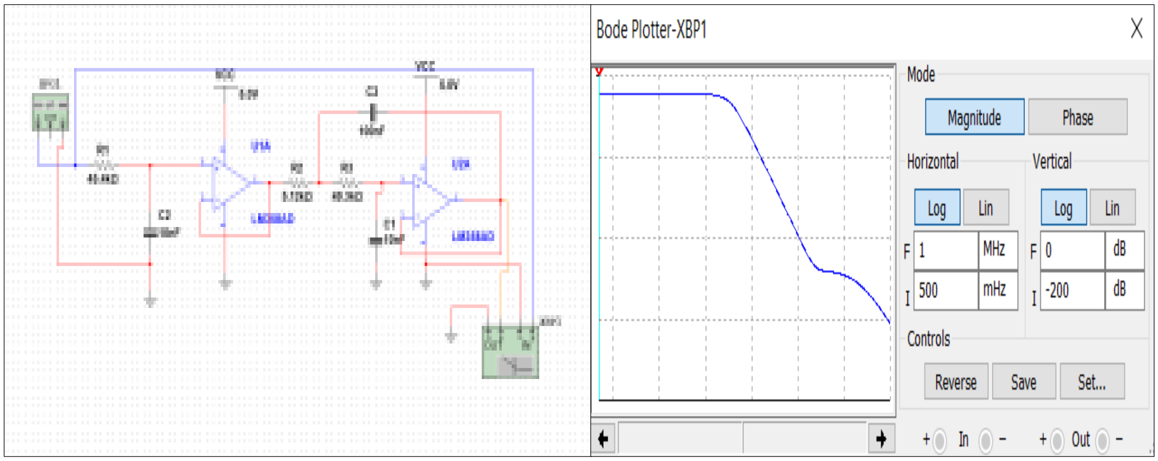

Figure: Sample 200Hz Low-Pass Filter using LM358 OpAmp

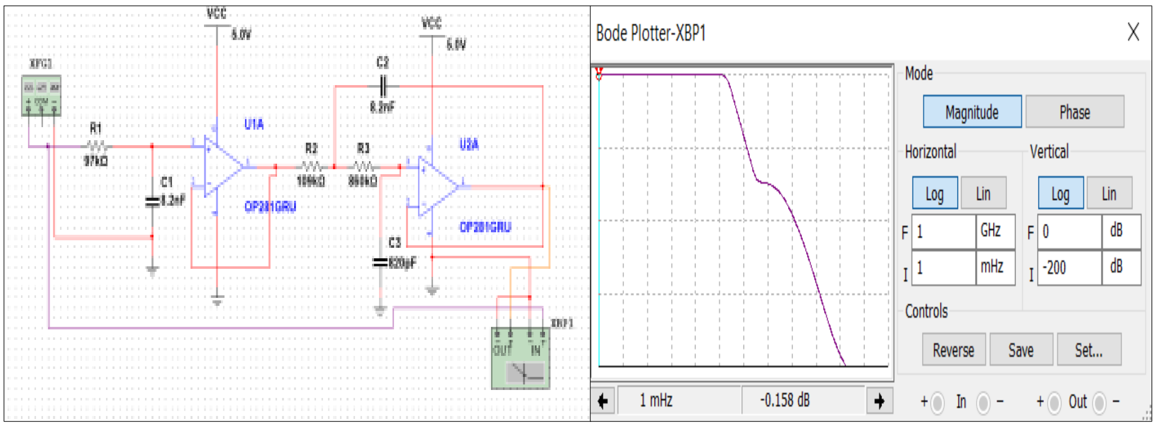

Figure: Sample 1kHz Low-Pass Filter using OP281 OpAmp

- Power Amplifier

  As we expect to utilize an earphone to get the final stethoscope output, we have to enhance the output power such that it is possible to hear the acoustic signal. Hence, it is needed to use an electronic device which could drive sufficient power with mismatching the input and output impedance levels at this stage with the final output device. Therefore, we have investigated the following options:

  1. LM358 Operational Amplifier
  2. LM386 Operational Amplifier

  We are yet to decide the overall suitability of the above components in order for achieving the power contrast and the other necessities.

Design and Unique Task Descriptions

After analysing the above requirements and design ideas thoroughly, we expect to fully characterize the subsystems with their finite requirement values.

Guiding Questions

1. Capability for using the above mentioned op-amps
2. Necessity for visual representation of the output signal
3. Verification, Validation and Quality Control Process
4. Safety Precautions
5. Data Sheet for the device