Multichannel Heart sound Signal Acquisition and Segmentation

A thesis submitted in partial fulfillment of the
requirements for the degree of

Bachelor of Technology

by

Deepak Meghwal (Roll No. 150108009)
Devesh Prajapat (Roll No. 150102015)

Under the guidance of
Prof. Samarendra Dandapat and Dr. L. N. Sharma

DEPARTMENT OF ELECTRONICS & ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Multichannel Heart Sound Signal Acquisition and Segmentation

is the work of

Deepak Meghwal
(Roll No. 150108009)

&

Devesh Prajapat
(Roll No. 150102015)

for the award of the degree of Bachelor of Technology, carried out in the Department of Electronics and Electrical Engineering, Indian Institute of Technology Guwahati under my supervision and that it has not been submitted elsewhere for a degree.

Guide

Date:

Place:

DECLARATION

The work contained in this thesis is our own work under the supervision of the guides. We have read and understood the “B.Tech Ordinances and Regulations” of IIT Guwahati and the “FAQ Document on Academic Malpractice and Plagiarism” of EEE Department of IIT Guwahati. To the Best of our knowledge, this thesis is an honest representation of our work.

Author

Date:

Place:

Acknowledgments

We would like to express my special thanks of gratitude to Prof. Samarendra Dandapat as well as Dr. LN Sharma who gave me the golden opportunity to do this wonderful project on the topic (Multichannel Heart Sound Signal Acquisition and Segmentation), which also helped me in doing a lot of Research and we came to know about so many new things we really thankful to them.

Secondly we would also like to thank our friends who helped us a lot in finalizing this project within the limited time frame.

Abstract

These days heart diseases are very common, more than30 people are suffering from heart disease out of 100 people. Acquisition of heart sound or listening to heart sound is an important process by which information for heart disease can be known and diagnosed. The conventional stethoscope requires highly trained and very good listening skill to acquire the heart sound. It is very difficult in the normal life to hear the heart sound and detect the murmurs or different kind of abnormality by just listening through the stethoscope. Hence, using electronic processing and further computer-heart signal auscultation eases the work of medical professionals and also helps in spreading the advantage of this very important technique to a greater audience. In this project , we are going to implement the two channel heart sound signal acquisition circuit and segment it using machine learning technique for better characterize and study in real time.

Contents

1. Introduction

By and large, in the twentieth century we see an eminent change in passings from transferable and irresistible sicknesses, for example, pneumonia , tuberculosis and flu towards non-transmittable maladies (NCDs, for example, coronary illness, malignant growths, diabetes and respiratory infection. Heart infections is the fundamental driver of passings since numerous years. As per WHO (World Health Organization) an expected 17.9 million individuals kicked the bucket from CVDs (Cardiovascular Diseases) in 2016, speaking to 31% of every single worldwide passing. Out f these passings, 85% are because of heart assault and stroke.

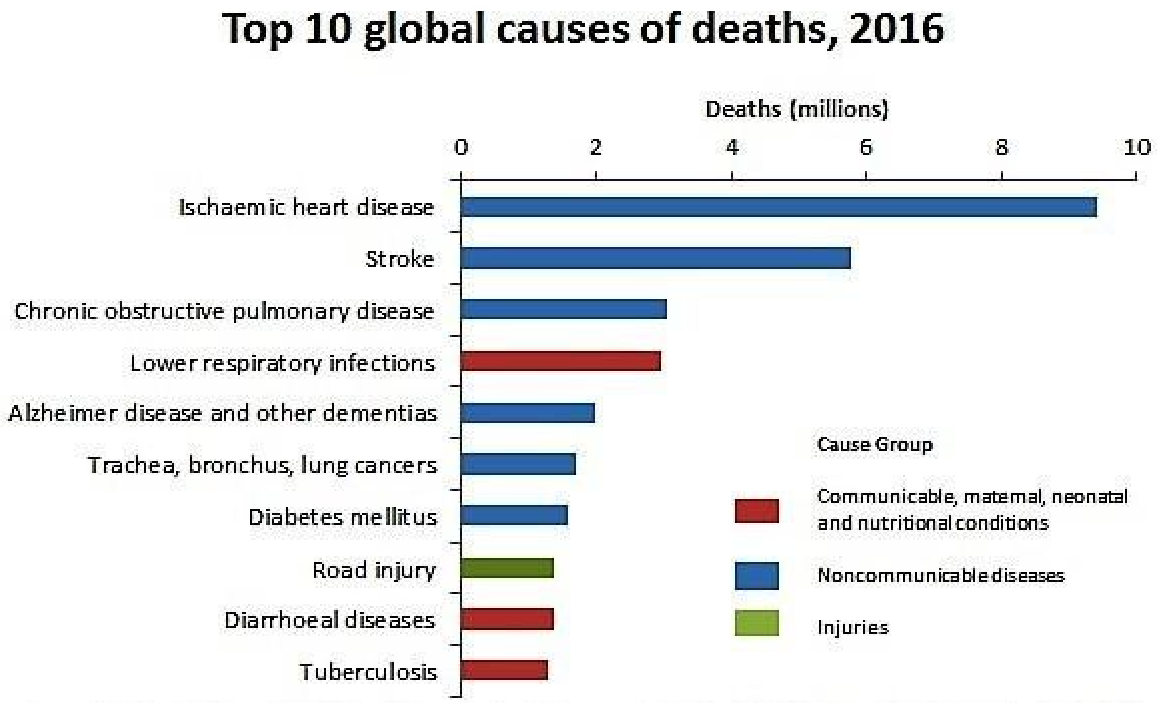

Fig 1.1 - Global Health Estimates 2016, WHO-2018

Finding is imperative in the decrease of death of coronary illness. ECG is an amazing apparatus utilized for heart treatment. It is savvy and simple to utilize . Be that as it may, there are a few impediments of this and one most normal is hard to process this apparatus. Nowadays there are different kind of heart imaging techniques(like - resound, MRI(Magnetic reverberation imaging) and CT(Computed tomography filter)) exist on the planet. Notwithstanding, the real inconveniences and disadvantages are that these are exorbitant and the need of specific staff to work the mind boggling machine. In this way, we require a practical and precise strategy for the early location of cardiovascular illness. Heart auscultation splendidly fits in the above job. Heart auscultation characterized as the tuning in and translation of the heart sound.

1.1 Literature Review

Wang Haibin & Hu Yuliang, Stated[3] that the heart sound measurement and analysis can be done by using the cardiac sound characteristic waveform method. This paper is concerned about the cardiac sound estimation and investigation system for in-home utilization of heart variation from the norm observing. The heart sound acquiring system is comprised of a customary chest-piece, headphone, receiver, IC recorder. The recorded information is transmitted to a PC by USB interface for examination dependent on cardiac sound characteristic waveform method.

Faizan Javed1, P A Venkatachalam and Ahmad Fadzil M H Stated[8] that a signal processing module (SPM) for the PC helped investigation of heart sounds has been created. The module uncovers essential data of cardiovascular issue and can help general doctor to think of progressively precise and dependable analysis at beginning periods. It can defeat the inadequacy of master specialists in provincial just as urban centers what's more, medical clinics. The module has five fundamental squares: Data Acquisition & Pre-processing, Segmentation, Feature Extraction, Murmur Detection and Murmur Classification.

2. Theory

Heart sound is generally the sound or confusion made by the throbbing of gushing of blood through heart vessels. It is delivered by the end or opening of different valves. Specifically, the sounds reflect the agitating impact made when the heart valves open and closes. There are two sort of Normal Heart Sound(as depicted in Figure) , much of the time depicted as a "lub" and a "dup" (or name), that occur in gathering with each heartbeat. These are the essential heart sound (S1) made before the finish of the atrioventricular valves and second heart sound (S2), conveyed before the finish of the semilunar valves.

There are assortments of sounds are additionally present like heart mumbles, dash rhythms of S3 and S4 other than ordinary sounds. These sound is ordinary in youngsters and grown-ups up to age 36– 45 years. Together they(S1 & S2) are called to as fundamental heart sound (FHS). A cardiovascular cycle or a solitary heartbeat is characterized as the interim between the start of S1 to the start of the following S1. The interim between the finish of S1 to the start of a similar cycle's S2 is called systole and the interim between the finish of S2 to the start of the following cycle's S1 is called diastole. Heart sound frequency go is for the most part 5-600Hz, above 120Hz is normally considered as high-frequency sound, 80Hz-120Hz as center frequency sound, beneath 80Hz as low-frequency sound, point by point frequency appropriation is appeared as pursues: S3 and S4: 10-50Hz; S1 and S2: 50-100Hz; thundering diastolic mumbles: 40-80Hz, some even reach to 140 Hz; high-frequency murmurs(systolic and diastolic whiffing systolic mumbles): 100-600Hz, some up to 1000Hz

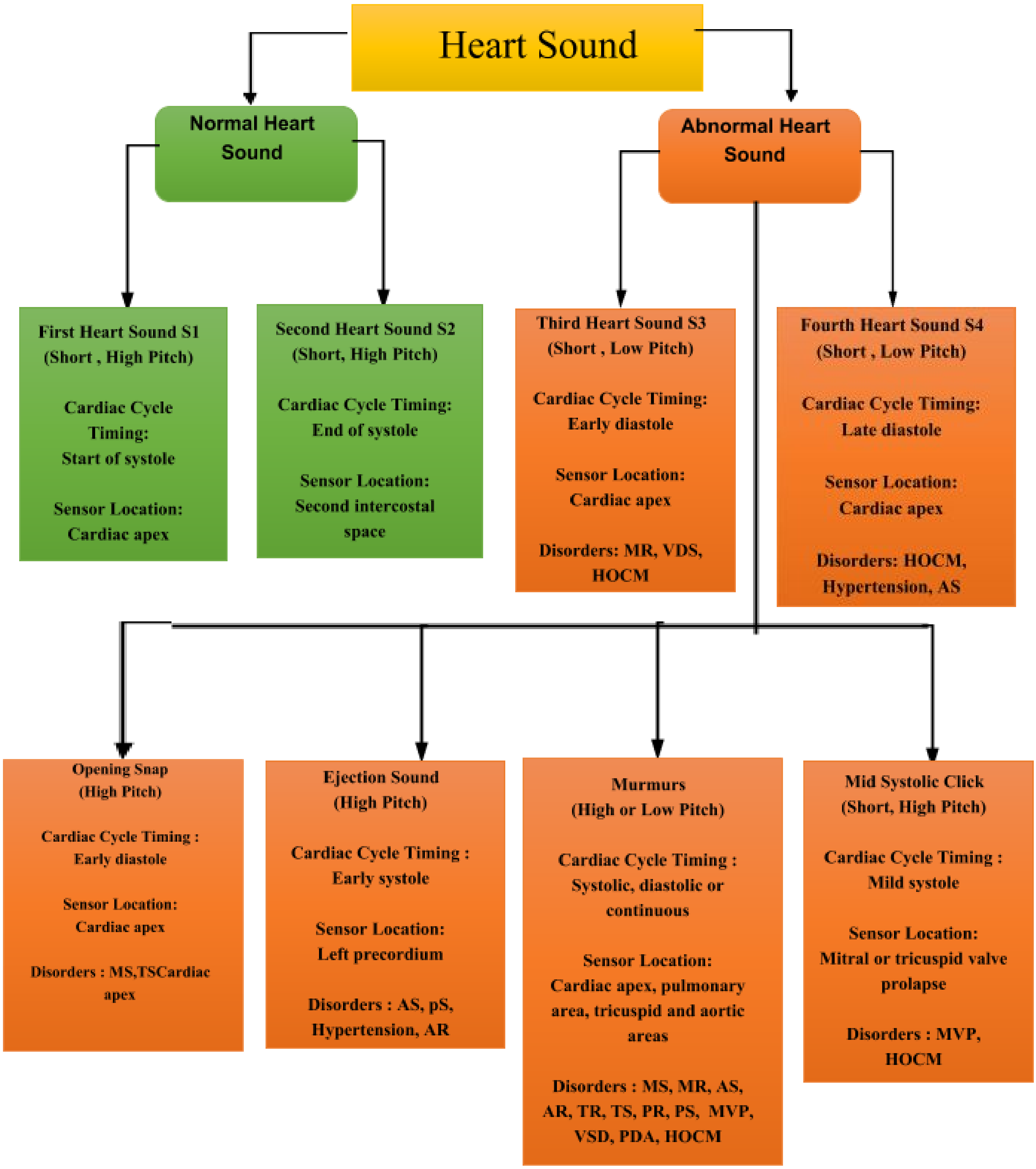

Fig 2.1 - Type of Heart Sound

2.1 First Heart Sound (S1)

The primary heart sound, or S1, frames the "lub" of "lub-dub". S1 heart sound is a low recurrence sound, and longest length, its happening toward the start of systole. S1 can be best heard over the apex, utilizing a stethoscope chime or stomach. The main heart sound is caused by disturbance made when the mitral and tricuspid valves close.

S1 have 4 main parts, the underlying vibrations happen when the principal withdrawal of the ventricle move blood towards the atria, shutting the AV-valves. The second segment is caused by the unexpected pressure of the shut AV-valves, decelerating the blood. The third part includes wavering of blood between the base of the aorta and the ventricular walls. The fourth segment speaks to the vibrations caused by choppiness in the launched out blood streaming to the supply routes. These parts might be recognized by time-recurrence deterioration.

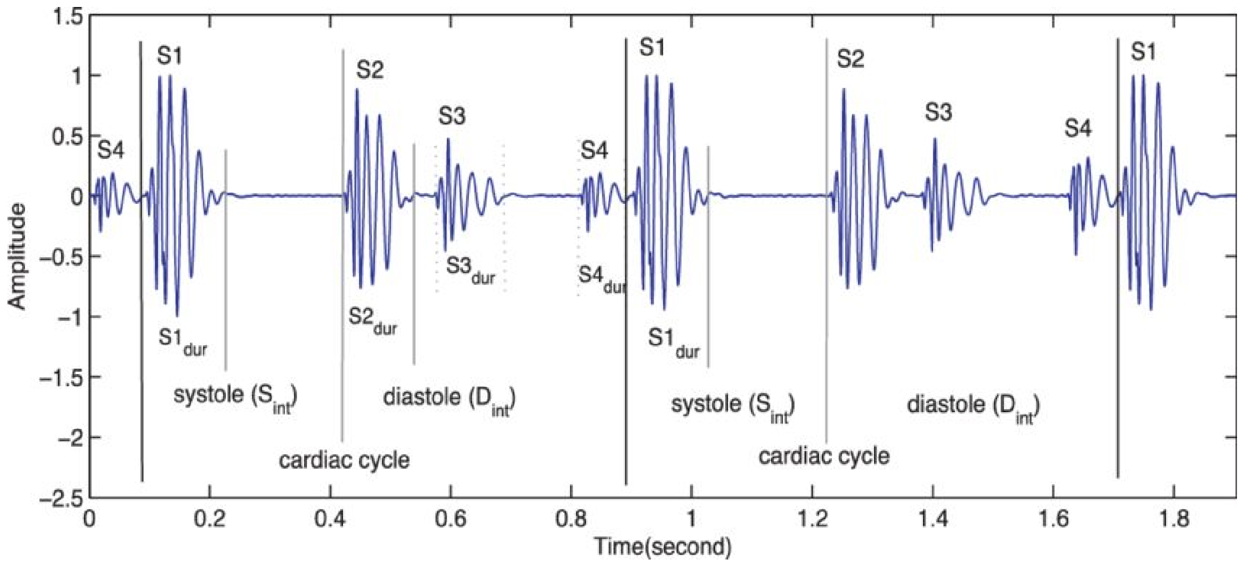

Fig 2.2-Waveform of Heart Sounds

2.2 Second Heart Sound (S2)

The second heart sound(S2) shapes the "name" of "lub-name" and is made out of parts A2 (aortic valve end) and P2 (pneumonic valve end). The S2 is conveyed before the finish of the semilunar valves (the aortic valve and aspiratory valve) at the complete of ventricular systole and the beginning of ventricular diastole. Commonly, its repeat is higher than S1, and its range is shorter. When the aortic valve is closed, the sound produced is named as A2, and when pulmonic valve is closed the sound produced is named as P2. Due to the high blood pressure in the left side of heart, the A2 become louder than P2 thus A2 is the main sound component of S2.

2.3 Third Heart Sound (S3)

The third low-frequency sound(S3) is a rare extra heart sound(HS), which occurs normally after two “lub-dub” heart sound. It occurs at the beginning of the middle third of diastole , approx 0.12 to 0.18 seconds after S2. It is associated with heart failure.

Heart Sound	Duration(Sec)	Frequency(Hz)
S1	0.1-0.12	50-80
S2	0.08-0.14	60-100
S3	0.04-0.05	<30
S4	0.04-0.05	<20

Fig 2.3 Duration and frequency range of different heart sound

2.4 Fourth Heart Sound (S4)

The fourth heart sound(S4) is an additional heart sound which happens amid late diastole, quickly before the ordinary two "lub-name" heart sound. It has short and low pitch. Its sensor area is at heart peak.

2.5 Murmur

Heart mumbles are the sound created when blood streams crosswise over one of the heart valves that are sufficiently boisterous to be heard with a stethoscope. There are 2 kind of mumbles. A "physiologic mumble" or "useful mumble" is a heart mumble that is principally because of physiologic conditions outside the heart. It might be the consequence of narrowing or spilling of valves. It has high or low pitch , and its cardiovascular cycle timing is systolic , diastolic or constant. Sensor area of this is cardiovascular zenith, pneumonic region, tricuspid and aortic territory.

2.6 Auscultogram from normal and abnormal heart sounds

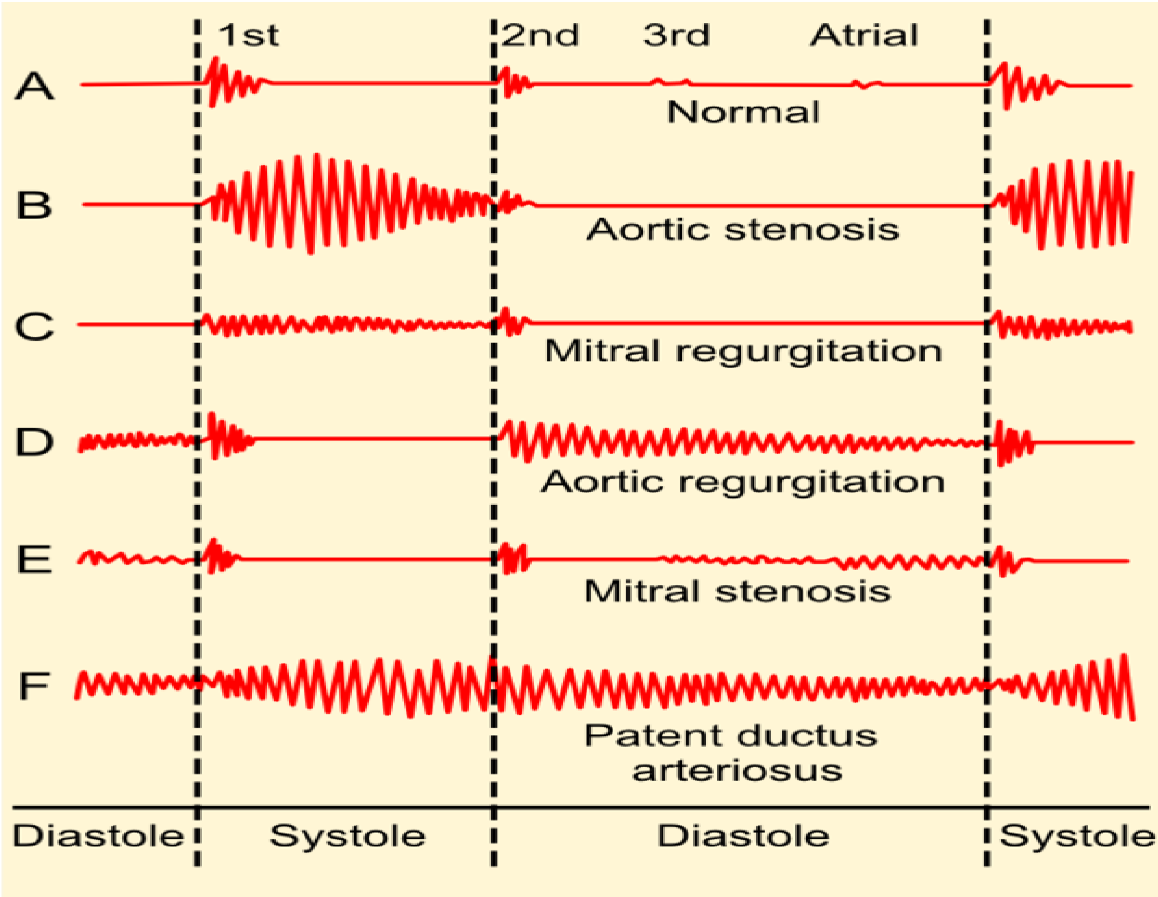

Fig 2.4 Normal and abnormal waveform of heart sound

2.7 Auscultation Areas

There are four important areas used for listening to heart sounds. These are: Aortic area(A), Pulmonic area(P), Tricuspid area(T), Mitral Area(M) (Apex).

- Aortic Valve Area 2nd right intercostal space(ICS), right sternal border
- Pulmonic Valve Area 2nd left intercostal space(ICS), left sternal border
- Erb's Point 3rd left ICS, left sternal border
- Tricuspid Valve Area 4th left ICS, left sternal border
- Mitral Valve Area 5th ICS, left mid-clavicular line

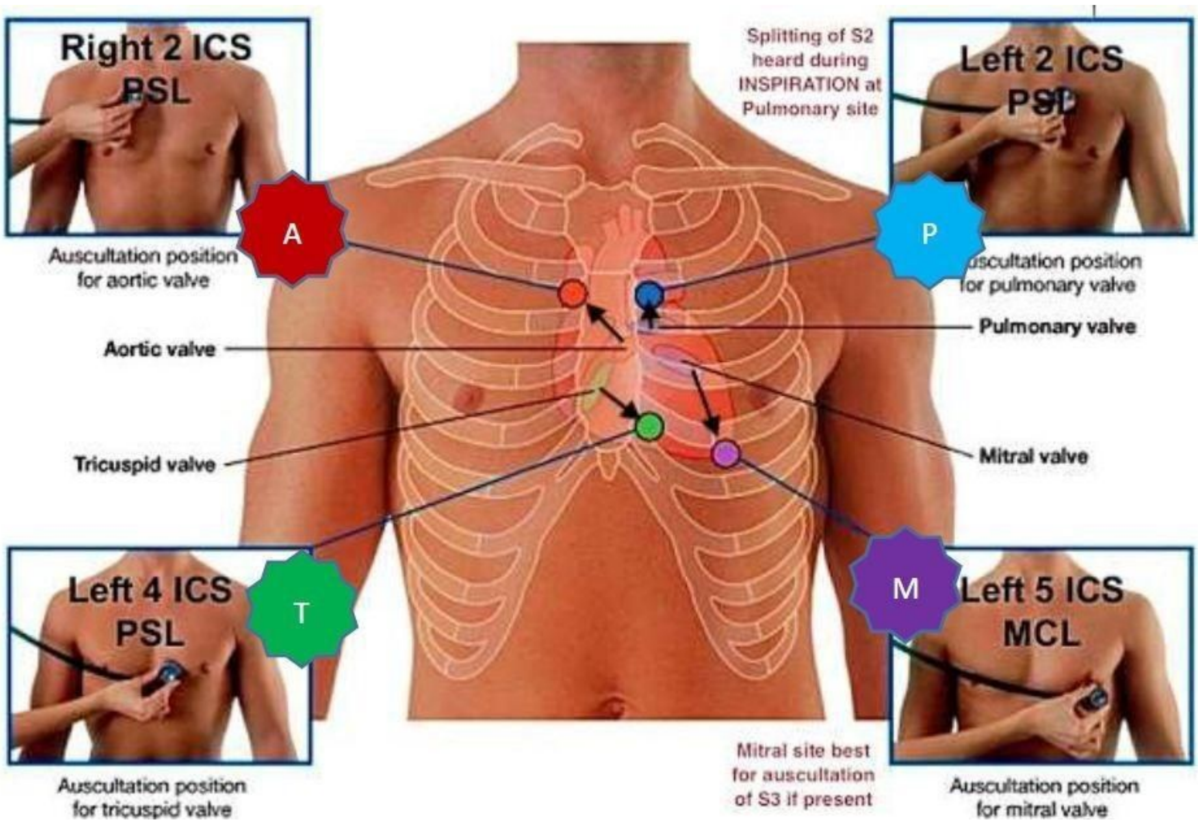

Fig 2.5 - Auscultation Areas

A general documentation for a heart motion at an auscultatory place is to utilize the main beginning of the site and the main or two to characterize the first or second heart sound individually. So T1 means the main heart sound at tricuspid territory and M2 characterizes the second heart sound at the mitral zone, and so on. T1 is marginally higher in flag and all the more boisterous at the tricuspid position. The A2 and P2 are best heard at the aortic and pulmonic destinations separately with the A2 sound being the fundamental part of the second solid heard at the apex.

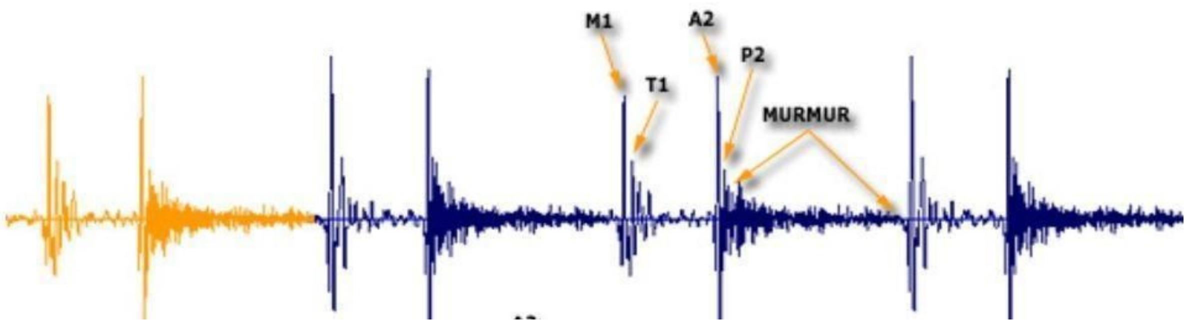

Fig 2.6-Auscultation Areas signal

3. Approach

3.1 Problem statement

The given problem statement for this project was to acquire the heart sound signal using four different conventional stethoscope with electret microphone from four different channels of the heart. Then the acquired heart signal should be segmented and processed in raspberry pi to collect the important data about the functioning of heart and murmur sound.

3.2 Approach

In this project , we are using four different conventional stethoscopes. Our circuit consiste two main parts for every channel.

1. Signal Acquisition
2. Signal Conditioning

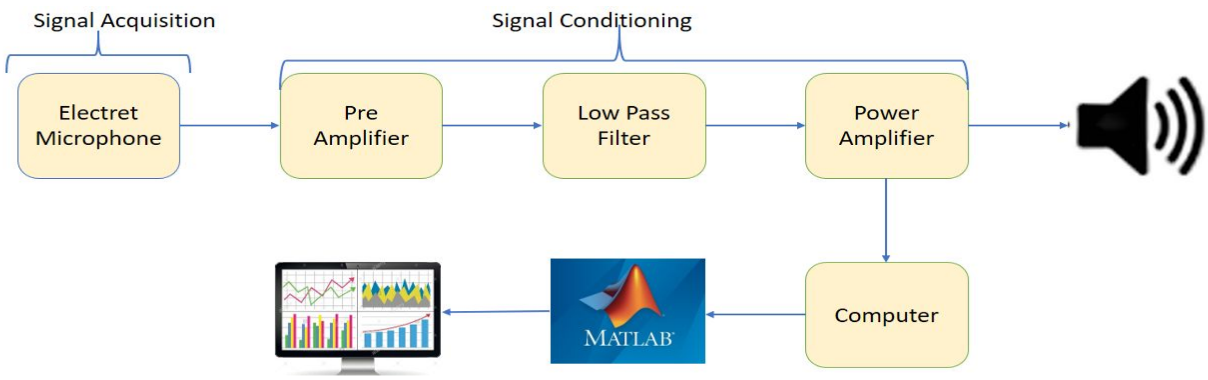

Fig 3.1 - signal acquisition and conditioning

In signal acquisition, we acquire the heart signal from electret microphone for this, we cut the stethoscope, and fit the microphone into it. Electret microphone consist a transducer and parallel plate capacitor, it works on the principle of a variable capacitance. One plate is fixed(called black plate) and other is movable plate(called diaphragm), due to sound pressure the diaphragm will move, and distance between parallel plate capacitor will change, hence the capacitance and voltage is changing.

3.3 Circuit Schematic

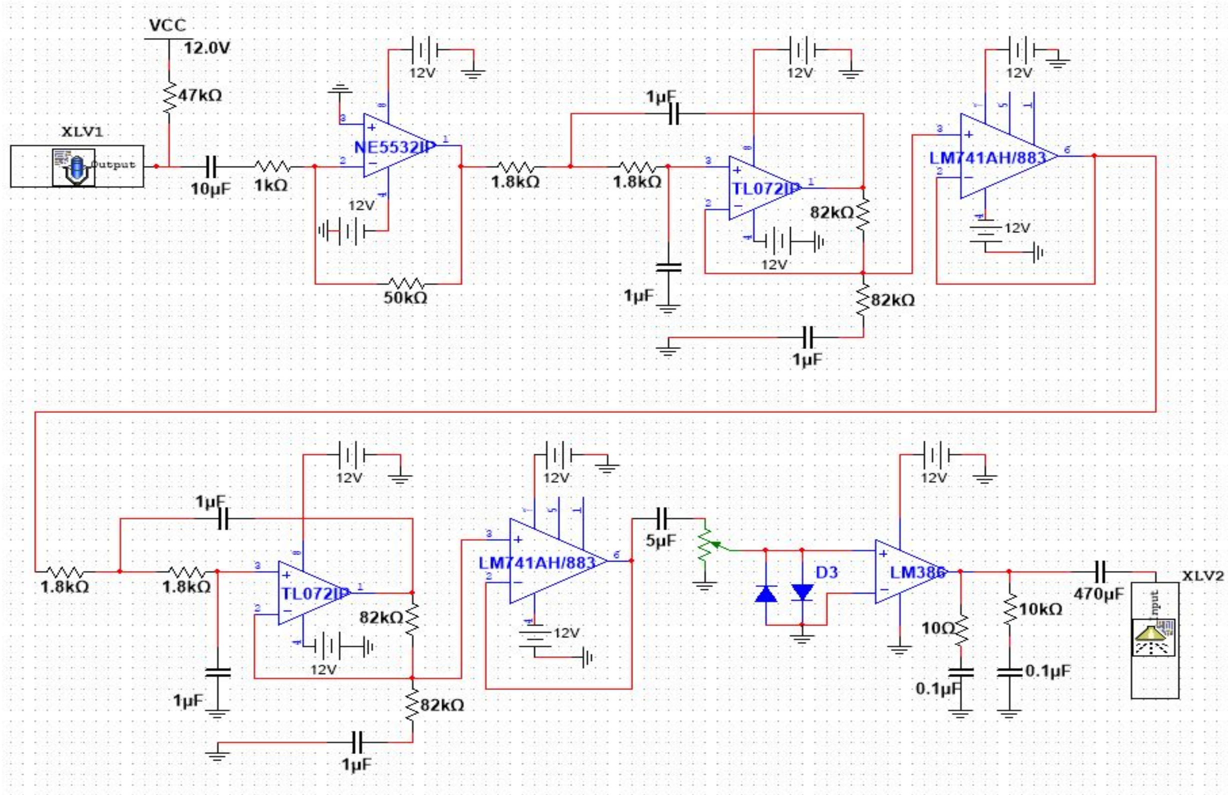

Fig 3.2 - Circuit Schematic

Signal conditioning is divided in three other sub-parts. Acquired signal is passed through pre-amplifier, a pre-amplifier is an electronic circuit that is used to convert a weak electronic signal to a signal strong enough to noise tolerant, without this the coming weak signal is very noisy and distorted and amplified signal is given to low pass filter. The filter passes the low frequencies components and reduce the noise. The signal comes from buffer circuit is not strong enough for driving loudspeakers or headphones. For handling this problem we are using a audio amplifier, its job is to amplifying the power of input signal.

So there are total four parts of signal conditioning for every channel circuit. The four parts are mentioned below:

- Pre-amplifier
- Low-pass filter
- Voltage Buffer
- Audio power amplifier

3.4 Pre-amplifier

A pre-amplifier is an electronic circuit that is used to convert a weak electronic signal to a signal strong enough to noise tolerant. Without this the coming weak signal is very noisy and distorted. An ideal preamplifier is linear and have high input impedance with low output impedance. The essential function of a preamplifier is to remove the signal from the detector without altogether corrupting the characteristic signal-to-noise ratio. Thusly, the preamplifier is situated as close as conceivable to the detector, and the info circuits are intended to match the attributes of the detector.

Microphone is biased by 12v and 47k ohm resistor. Signal coming from microphone is very weak , so preamplifier does the signal strong enough to be noise tolerant and strong enough for further processing. Pre-amplifier consist the gain of 50. It is using the IC NE5532 , which has very low noise ratio , high output drive capability and high slew rate.

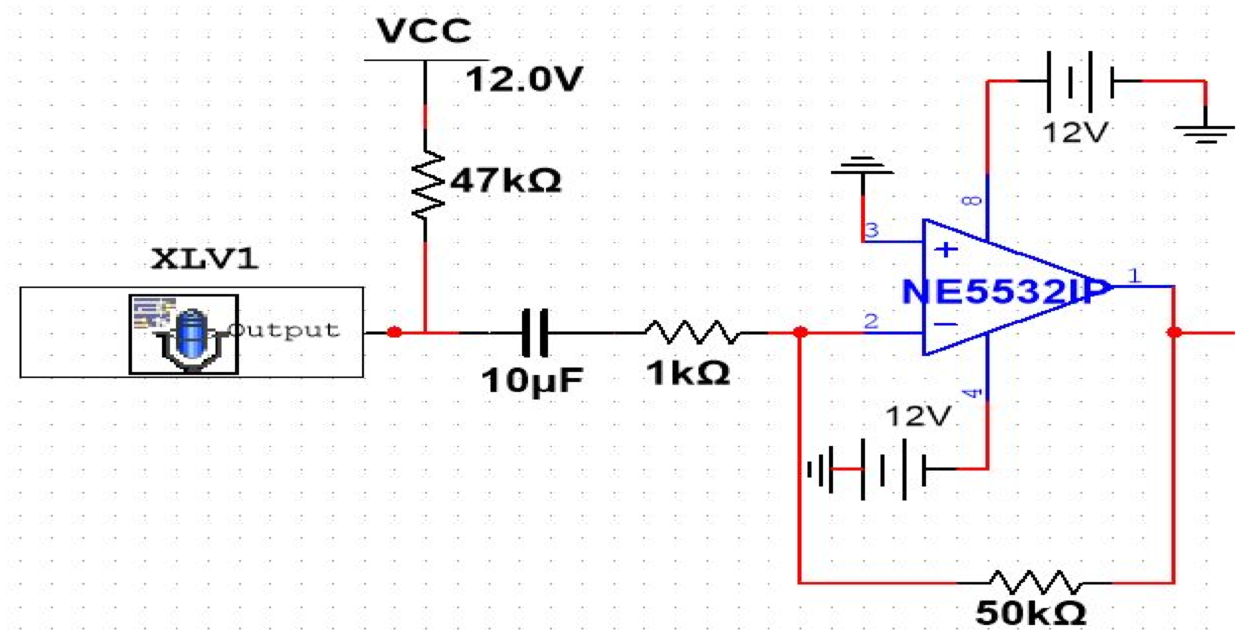

Fig 3.3- Preamplifier

3.5 Low-pass filter

Low pass filter passes the low frequencies(less than cutoff frequency) components and attenuate the high frequencies(greater than cutoff frequency) components. Heart sounds are mostly contained in frequencies less than 90Hz. So, we designed the 4th order butterworth filter(special type of low pass filter), its cutoff frequency is around 90Hz. We can not directly design the 4th order filter , so we made two separate 2nd order butterworth filter and concatenated them.

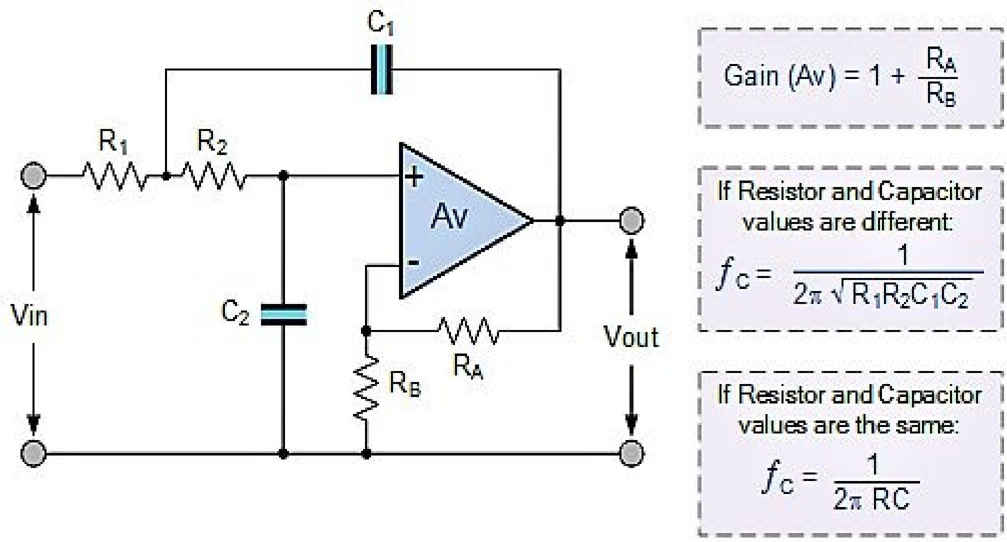

Fig 3.4 - 2nd order butterworth filter

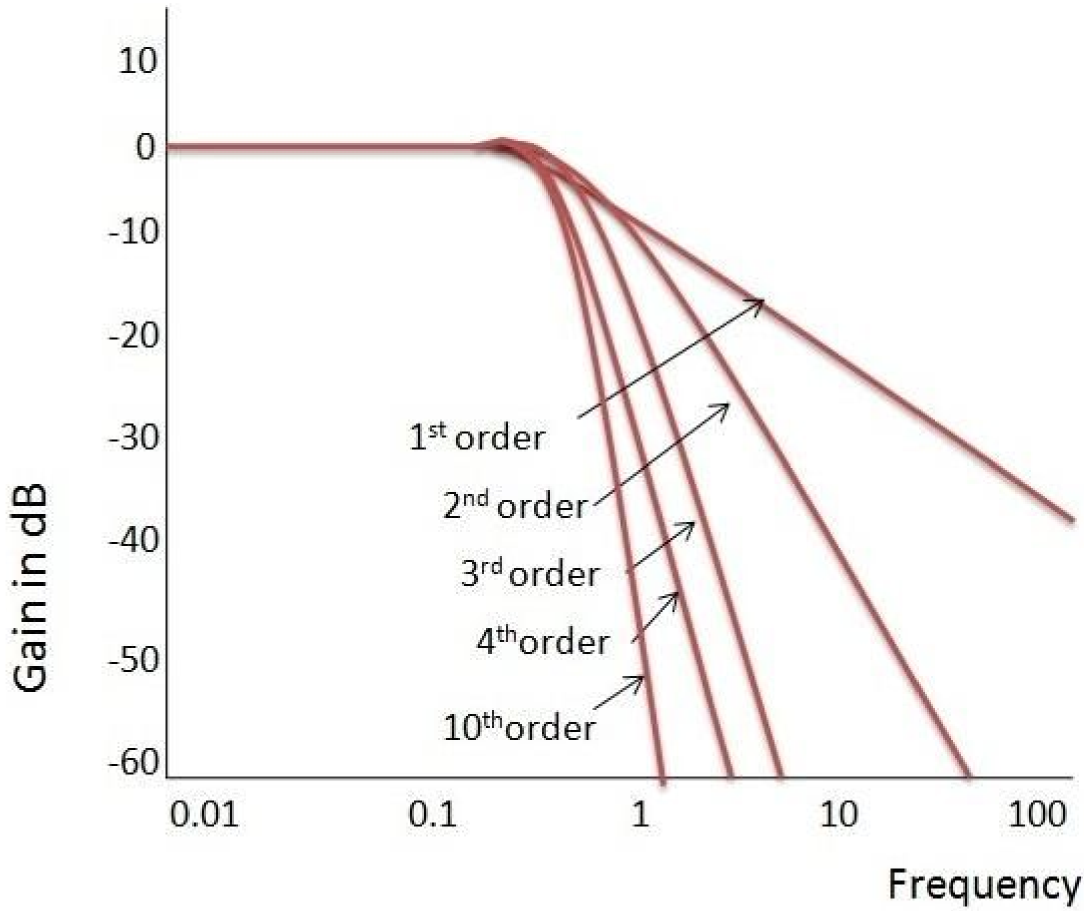

Fig 3.5 - Gain(in db) vs Frequency

Butterworth Filter

A Butterworth filter does maximally time flat in the pass-band. At the cut-off frequency, fc, the attenuation-factor is - 3dB. Over the - 3dB point the attenuation is moderately steep with a move off of - 20dB/decade/post. In all Butterworth filters, the cutoff frequency is given by $1/2\pi RC$. By and large, a two post filter produces 20 dB for each decade; a four-poles produces 80 dB for each decade. In two shaft low pass filter, the flattest conceivable reaction in the mid band can acquire for the gain 1.586. A four shaft low pass filter, a course of a two-post and another two shaft. A development induction demonstrates that the required the close loop gain ACL =1.152 for the second order filter and ACL =2.235 for the fourth order filter.

For designing the second order butterworth filter, we are using IC TL072 (JFET input Op Amp). This IC has desirable features like low noise, high slew rates and low harmonic distortion. Filter consist the R1=R2=1.8k ohm and C1=C2=1uF, R3=R4=82k ohm.

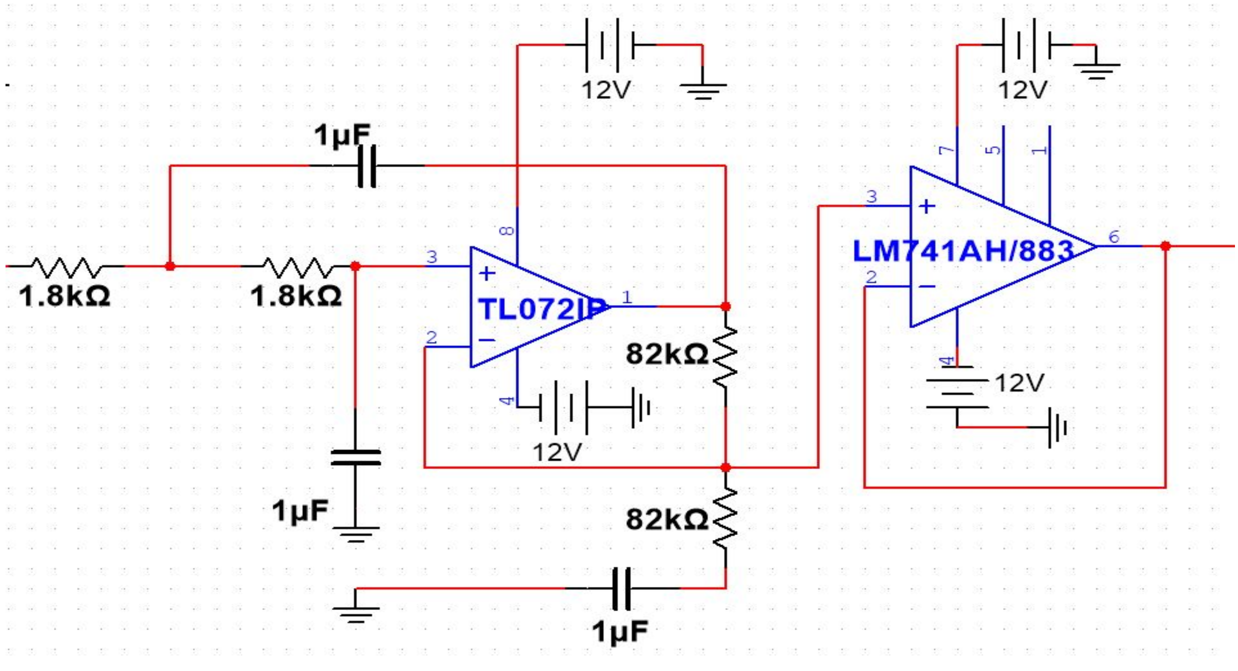

Fig 3.6 - Butterworth filter with voltage buffer

3.6 Voltage Buffer

Voltage follower is an Op-amp circuit whose yield voltage straight away follows the information voltage. That is yield voltage is proportionate to the info voltage. Operation amp circuit does not give any intensification. In this way, voltage gain is equivalent to 1. They are like discrete producer follower. Different names of voltage follower are Isolation Amplifier, Buffer Amplifier, and Unity-Gain Amplifier. The voltage follower gives no weakening or no intensification however just buffering. This circuit has a beneficial normal for exceptionally high info impedance. This high info impedance of voltage follower is its reason being utilized in a few circuits. The voltage follower gives a productive disconnection of yield from the information flag. For designing this, we used the IC 741(Basic Op amp), it has Vout = Vin. The circuit of voltage follower is appeared as follows.

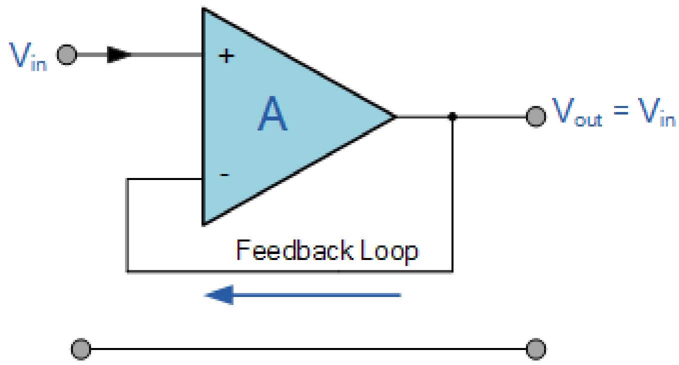

Fig 3.7 - Buffer Circuit

3.7 Audio Power Amplifier

The signal comes from buffer circuit is not strong enough for driving loudspeakers or headphones. For handling this problem we are using a audio amplifier, its job is to amplifying the power of input signal or low signal. Its implementation is done by IC LM386 , which is a low voltage audio power amplifier. The gain of power amplifier has been kept variable with the help of potentiometer. This is the last stage of signal conditioning. In addition , protection diodes have been used to protect the unwanted damage. The output of this circuit is fed into the loudspeaker or headphone.

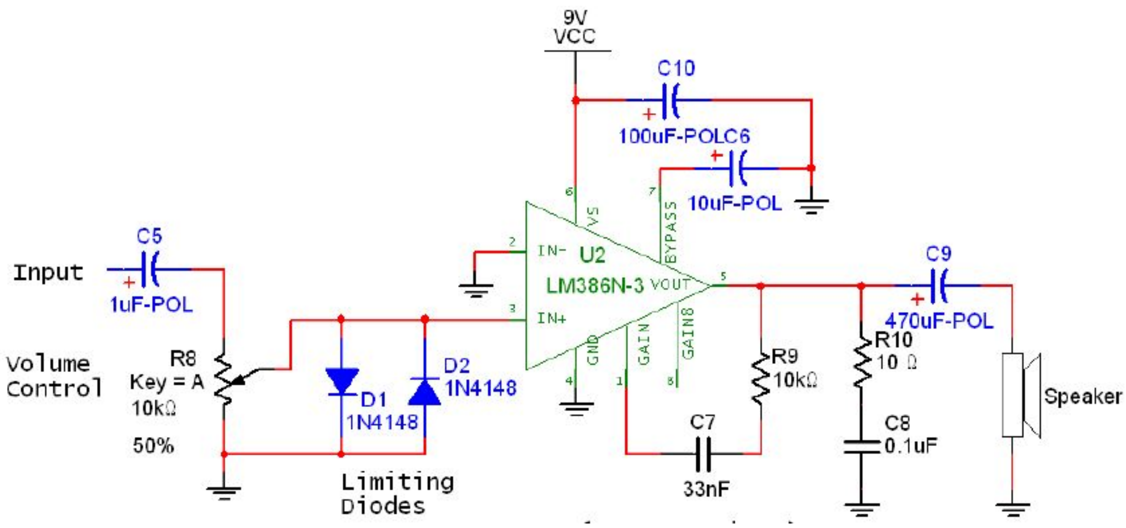

Fig 3.8 - Audio amplifier

3.8 Heart Sound Analysis

Heart sound analysis(HSA) can be broken into three parts.

1. segmentation
2. feature extraction
3. classification.

Segmentation is to decide the limits of cardiac cycles from adjoining heart sound signs. Feature extraction is to figure the recognizing parameters from each cardiac cycle. Classification is to settle on a choice on a heart sound's sort dependent on those parameters. There are two ways to deal with segmentation: envelope based and machine learning based. Most existing calculations utilize the envelope approach since it isn't important to name distinctive segments of cardiac cycles physically. Then again, whenever marked cardiac cycles are accessible, at that point a machine learning approach is favored on the grounds that repetitive envelope analysis can be evaded.

Segmentation

Segmentation has been the subject of numerous examinations since it is the first and maybe the most troublesome step in heart sound analysis. The most well known way to deal with segmentation can be known as the "envelope analysis" approach. This methodology computes the envelope signal of a heart sound, distinguishes peaks of the envelope signal, builds up which peaks compare to S1 and which relate to S2 and, at that point shapes cardiac cycles utilizing the S1-S2 intervals.

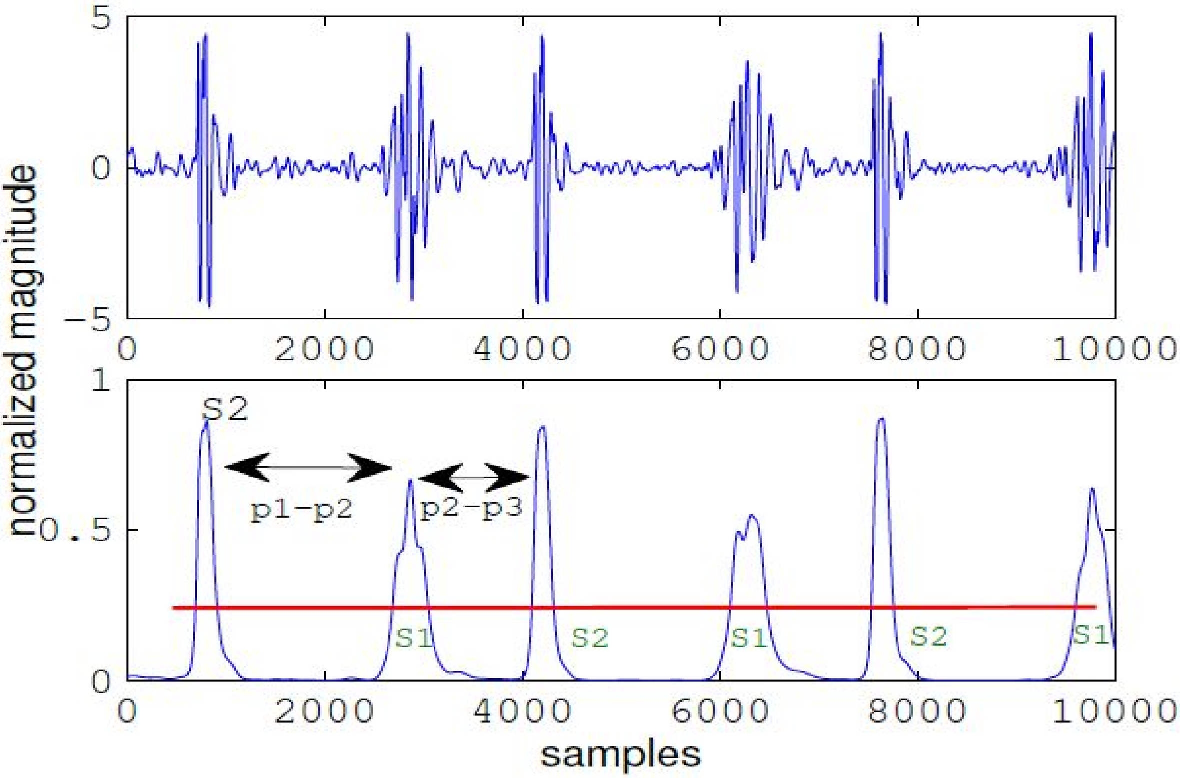

Fig 3.9 - Segmentation of heart sound

Feature Extraction

Feature sets found in the writing can generally be assembled into two kinds. The first utilizes medicinal learning about explicit diseases and how they influence the age of heart sounds. A case of a feature of this sort is the part S2 interval. Numerous cardiac issue cause S2 to part into two separate sounds. Different sorts of features depend on time-recurrence flag portrayals. This kind of portrayal is especially appropriate for heart sounds since they are non-stationary signs whose recurrence content changes with time. A specific time-frequency representation usually utilized in heart sound investigation is the discrete wavelet transform(DWT). Also, DWT coefficients are unaffected by the kind of envelope detection strategy utilized, since they are determined legitimately from heart sound signs.

3.9 Circuit

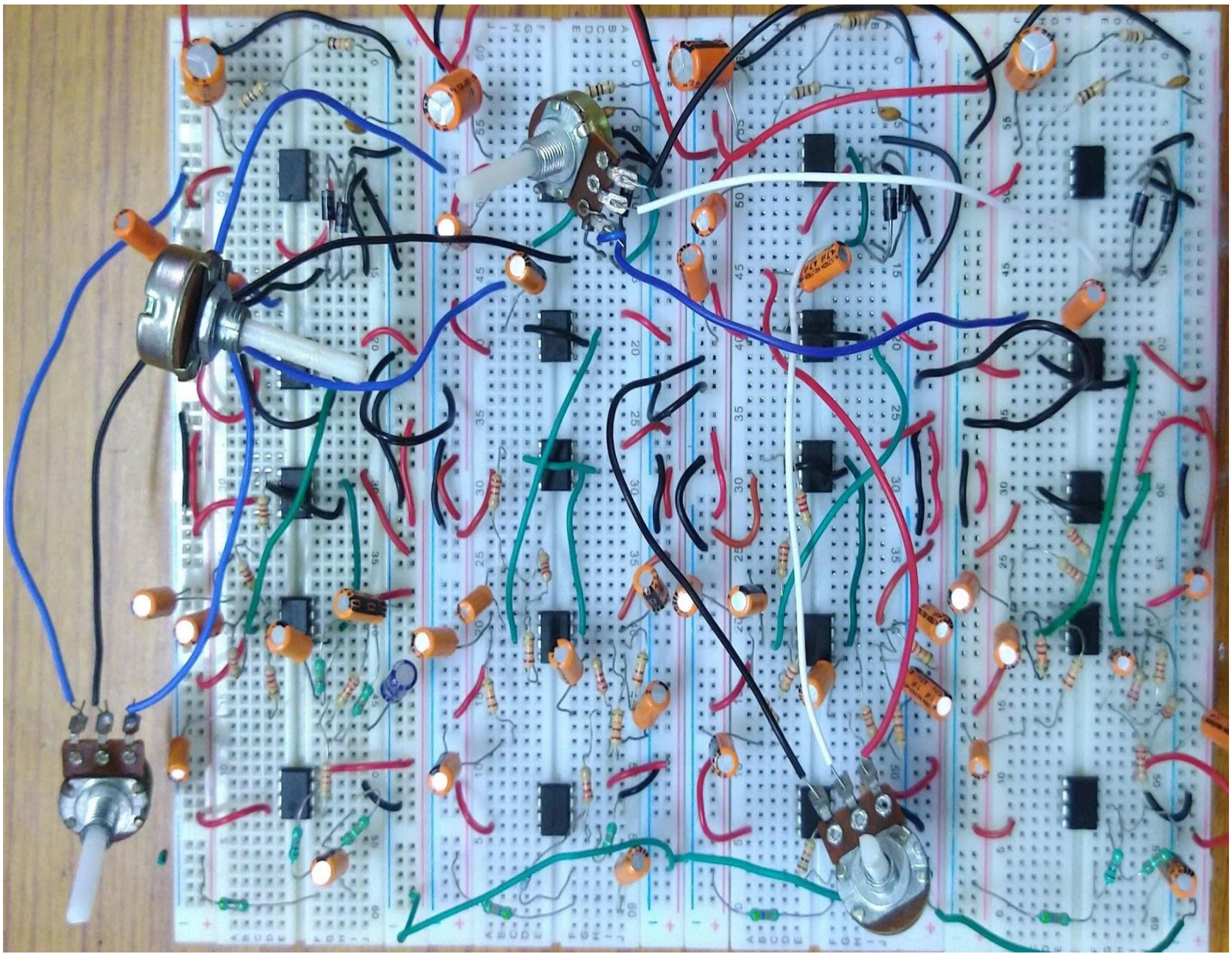

Fig 3.9 - 4 channel acquation circuit

4. Observation

4.1. One Channel output

We Observed waveform of heart sound on different stages with different time scales. First we observed each channel output from different locations of heart's valves (4 different valves - mitral valve(M), tricuspid valve(T), aortic valve(A), pulmonary valve(P)) and these location are mentions in 2.7 (Auscultation Areas topic).By the help of audio jack and headphone we can change electriacl signal in to sound signal. We clearly heard the heart sound of our heart from different valve's locations.

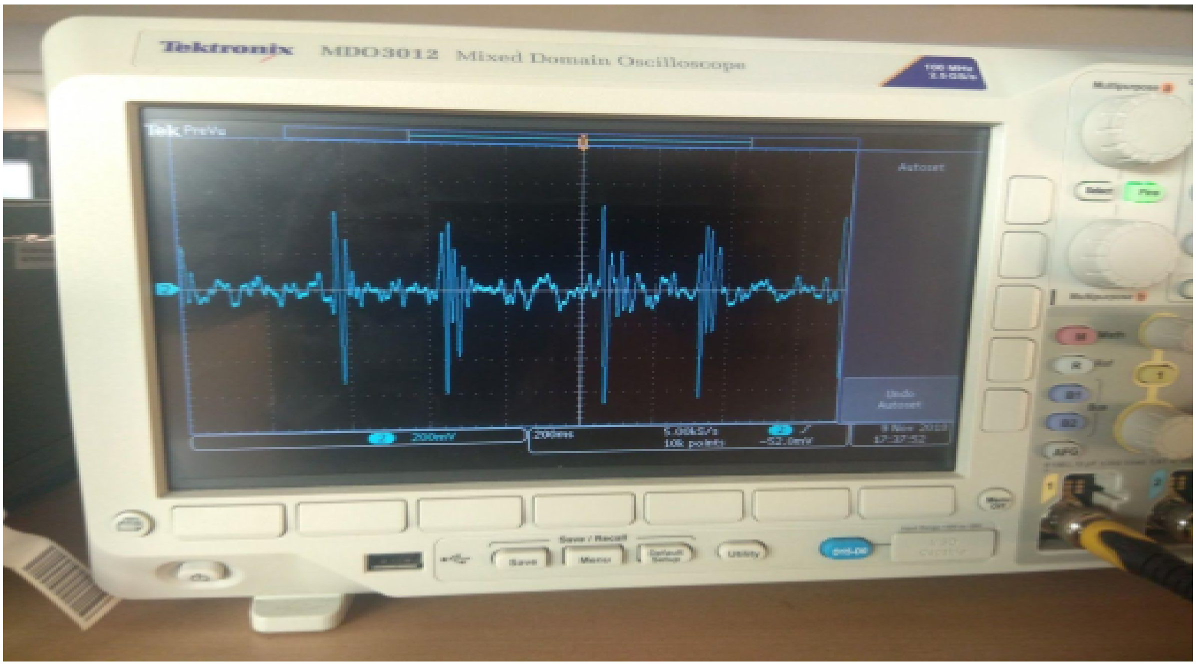

Fig 4.1, 4.2 - Output of audio amplifier with different time scales of one channel

4.2. Four channel

For observing 4 channels heart sound signal simultaneously, we used 4 channel oscilloscope. We clearly observe the S1, S2, S3 and S4 heart sound in oscilloscope. Output of the preamplifier has little noises , but when we passed that signal through filter then noise has been removed. We can see very clear output at the stage of power amplifier.

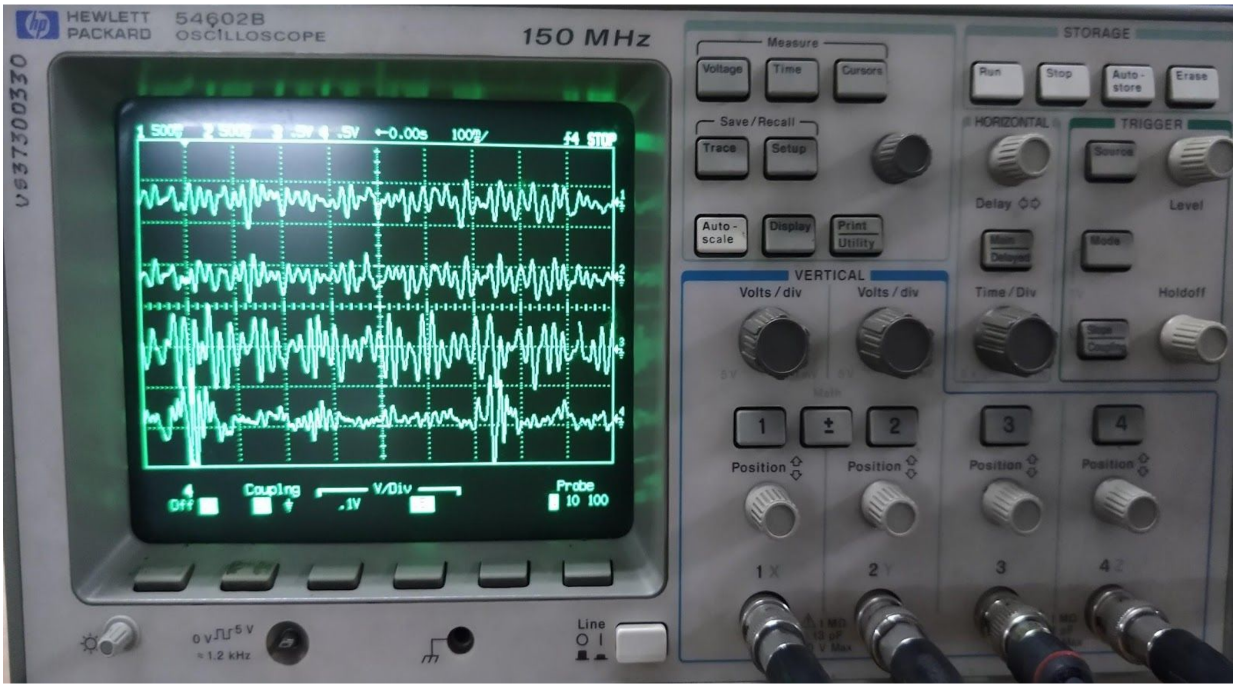

Fig 4.3, 4.4 - output of 4 channels acquistion circuit

5. Precaution

- Electret microphone is highly susceptible to noise, so we fixed the microphone in convenstational stethoscope such a way that, there is no air passes through it except, from the diaphragm of mechanical stethoscope, hence the biggest noise insertion point will remove.
- The connection of wires should be done properly. Loose connection should be avoided in the circuit.
- The voltage of power supply should not exceed +12 and -12 and should be connected properly with ground terminal connected to the circuit as well.
- The second order filter does not have the sharp amplitude drop at cutoff frequency or at the high frequencies side, so we used the 4th order butterworth filter, which has sharper drop than the 2nd order butterworth filter.
- As the frequency is high, its attenuate factor is go high, so its amplitude go down. Hence we removed the high frequency components from the signal.
- We carefully designed the audio power amplifier to efficiently play the heart sound via the speaker or headphone. We tuned this circuit for getting the high amplitude of output, so we can hear clear and loud sound of heart signal.
- We were using the breadboard to build the circuit , due to loose connection between the wires and components, or some time they touch to each other. so we were not getting correct output. For handling this we have to build our circuit on veroboard.

6. Results

- First we implemented a single circuit for signal acquisition of one channel and successfully got the waveform of heart sound signal.
- We successfully implemented four channel heart sound signal acquisition circuit. We clearly observed the S1 and S2 heart sound in a four channel oscilloscope from four different channels of heart using four different stethoscopes.
- Heart Signal was acquired from different stethoscopes using the electret microphones connected in every stethoscope.
- This signal that we get by electret microphone of stethoscope was very low and full of noise, so it was hard to process the signal for further signal conditioning. So to avoid this and to make the low noise signal to high signal we amplified the signal using pre-amplifier and got the amplified signal.
- The amplified signal was passed through fourth order butterworth filter as it contained noise after being passed through pre-amplifier. The cut-off frequency of butterworth filter used is 90Hz. The fourth order butterworth filter was implemented by concatenation of two second order butterworth filters.
- Due to weak electrical signal, we cannot feed into the speakers, so it was amplified using audio power amplifier.

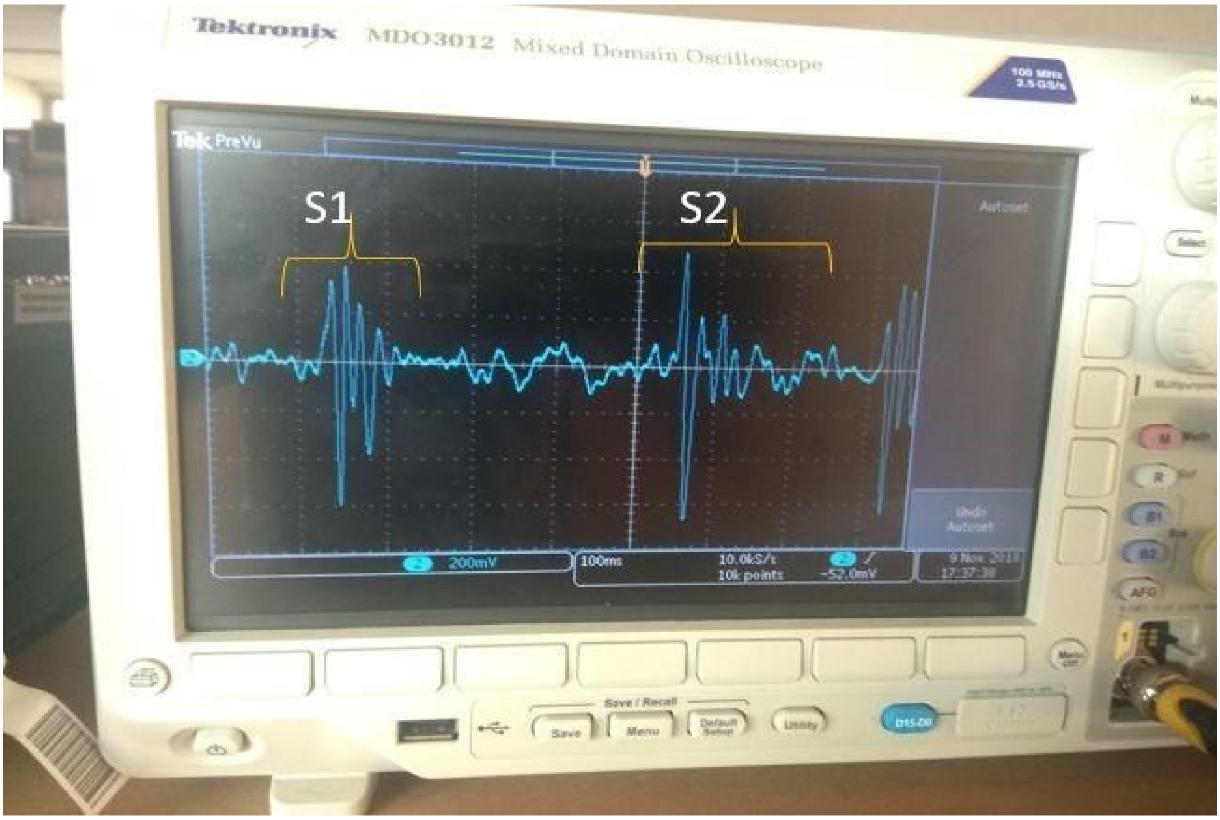

Fig 6.1 - Acquire the S1 and S2 heart sound

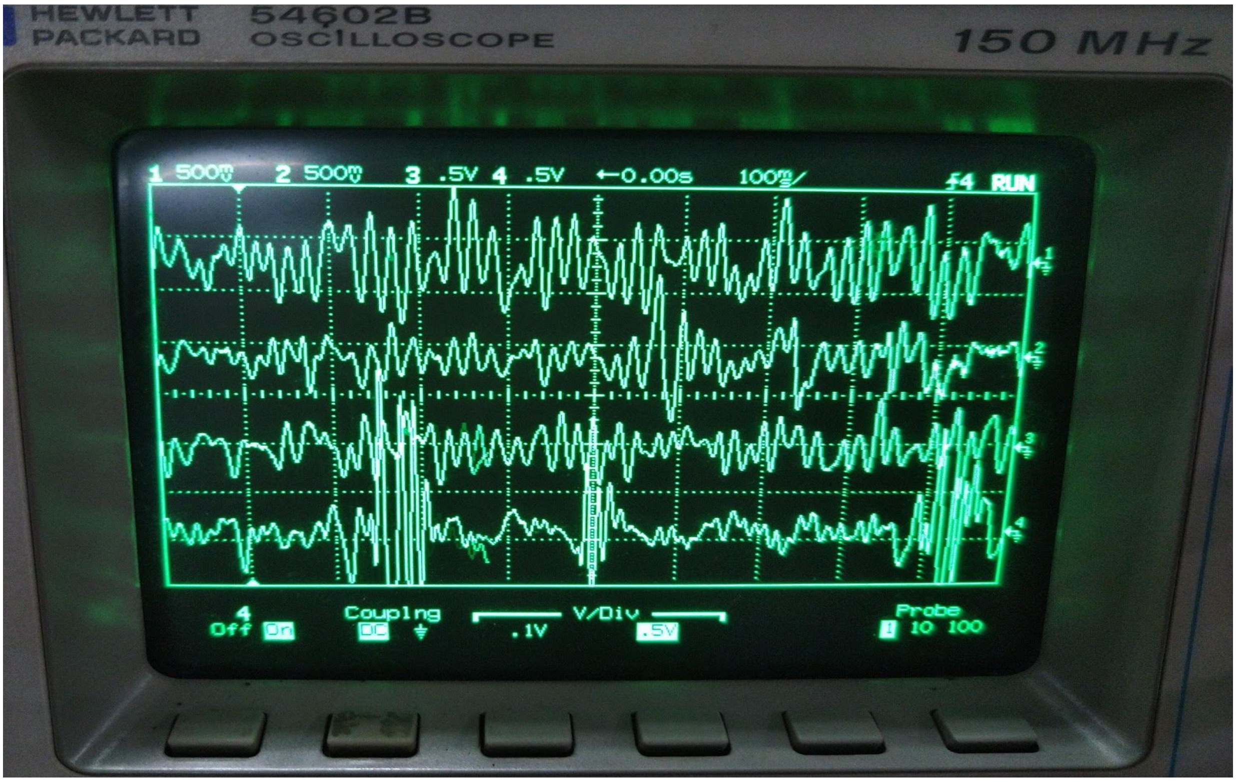

Fig 3.9 - Final result of 4 channel acquisition circuit

7. Future work

- The heart sound signal can be segmented using machine learning techniques for knowing the characteristics and study of heart sound in real time. A software can be made which can take the acquire heart signal and segment it into S1,S2,S3,S4 , tell about the dysfunction of heart.
- Along the lines of our aim of building a robust product that can be easily used by researchers/ doctors, the circuit can be transfered to a PCB board and a raspberry pi 3 can be used as the compute system for the software analysis.

8. Bibliography

1. MB Malarvili, M Najeb, I Kamarulafizam, S Hussain, “Two Channel Data Acquisition System for Heart Sound Segmentation Algorithm Based on Instantaneous Energy of Electrocardiogram”, Department of Microelectronics and Computer Engineering, UTM-Skudai Johor, Malaysia

2. Sumeth Yuenyong, Akinori Nishihara, Waree Kongprawechnon, Kanokvate Tungpimolrut, “A framework for automatic heart sound analysis without segmentation”, Bio-Medical Engineering OnLine 2011

3. Wang Haibin, Hu Yuliang, Jiang Zhongwei, Zhang Junqi, Choi Samjin, Sun Shuping, “Heart Sound Measurement and Analysis System with Digital Stethoscope”, Asia International Symposium on Mechatronics 2008, 27-31 August 2008 Hokkaido University, Japan

4. Khudhur A. Alfarhan, Mohd Yusoff Mashor, Abdul Rahman Mohd Saad, Mohammad Iqbal Omar, “Wireless Heart Abnormality Monitoring Kit Based on Raspberry Pi”, Journal of Biomimetics, Biomaterials and Biomedical Engineering, ISSN: 2296-9845, Vol. 35, pp 96-108, https://www.researchgate.net/publication/322645733

5. Zhenyu Guo, Chris Moulder, Louis-Gilles Durand, Murray Loew, “Development of a virtual instrument for data acquisition and analysis of the phonocardiogram”, Department of Electrical Engineering and Computer Science, The George Washington University, Washington, DC 20052, USA, 20th Annual International Conference of the ZEEE Engineering in Medicine and Biology Society, Vol. 20, No I , 1998

6. Fabio de Lima Hedayioglu. Heart Sound Segmentation for Digital Stethoscope Integration. https://repositorio-aberto.up.pt/bitstream/10216/22169/4/MasterThesis.pdf

7. Simarijot Kaur Randhawa and Mandeep Singh, “Classiication of Heart Sound Signals Using Multi-modal Features”, www.sciencedirect.com

8. Faizan Javed1, P A Venkatachalam2 and Ahmad Fadzil M H, “A Signal Processing Module for the Analysis of Heart Sounds and Heart Murmurs”.

9. MB Malarvili, M Najeb, I Kamarulafizam, S Hussain, “Two Channel Data Acquisition System for Heart Sound Segmentation Algorithm Based on Instantaneous Energy of Electrocardiogram”, Department of Microelectronics and Computer Engineering, UTM-Skudai Johor, Malaysia

10. S. Haykin, “Cognitive Radio: Brain Empowered Wireless Communications,” *IEEE Journal on*

11. Christer Ahlstrm. Methods for the Intelligent electret Stethoscope. Processing of the Phonocar-diographic Signal, 2006.

12. Cliord, G.D., Signal processing methods for heart rate variability analysis (St.Cross College).

13. Zhenyu Guo, Chris Moulder, Louis-Gilles, Murray Leow, Development Of A Virtual Instrument For Data Acquisition Of The Phonocardiogram, Conference of the IEEE ,Vol. 20, No 1, 1998.

14. Amin, D.S.M. and Fethi, B., Features for Heartbeat Sound Signal Normal, Vol. 1 (London, UK: Bentham Publishers), pp. 1-8.

15. https://ieeexplore.ieee.org/document/5305303