TEACHING STETHOSCOPE

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ABSTRACT

Teaching Stethoscope is one of the latest biomedical gadgets which have been constructed in this project. This project is implemented by constructing hardware and software design. Basically, this project is divided into three categories which are signal amplification, wireless transmission and computer display. The components that involve in constructing hardware are stethoscope, microphone, instrumentation amplifier, buffer, integrator, low pass filter, audio amplifier and speaker. This part is the heart of the project whereby the signal will be captured through microphone and amplified with the instrumentation amplifier. It will be then filtered by an integrator and low-pass circuit below 200 Hz to reduce the noise. There will be two approaches of displaying the signal in the computer which is MATLAB and Microcontroller 89C51. This analog signal will be converted to digital signal by ADC before it is sent to the microcontroller. By using microcontroller 89C51 as data connection heart pulse are shown in LABVIEW software. The second option will be connecting the hardware to computer through microphone jack and display it through MATLAB in a pulse form. Wireless transmission involves the implementation of FM transmitter and FM receiver. Finally, output signal from the FM receiver will be amplified by using audio amplifier to be heard through the speaker.

ABSTRAK

Stetoskop Pengajar merupakan salah satu peralatan bioperubatan terbaru yang direka dalam projek ini. Implimentasi projek ini meliputi aspek perkakasan dan perisian. Secara amnya, projek ini terbahagi kepada 3 bahagian iaitu penguatan isyarat, penghantaran tanpa talian dan pemaparan pada komputer. Antara komponen yang terlibat dalam rekabentuk perkakasan adalah stetoskop, mikrofon, penguat peralatan, litar penimbal, litar pengamir, litar penuras laluan rendah, litar penguat audio dan pembesar suara. Bahagian perkakasan merupakan bahagian yang terpenting dalam projek ini dimana isyarat akan ditangkap menerusi mikrofon dan akan dikuatkan dengan litar penguat peralatan. Isyarat tersebut kemudiannya akan dituras menerusi litar pengamir dan litar penuras laluan rendah kebawah 200Hz untuk mengurangkan hangar. Terdapat dua kaedah untuk memaparkan isyarat pada komputer iaitu dengan perisian MATLAB dan mikropengawal 89C51. Isyarat analog ini akan ditukarkan kepada isyarat digital menerusi ADC sebelum ia dihantar ke mikropengawal. Dengan penggunaan mikropengawal 89C51, perisian LABVIEW telah digunakan untuk pemaparan isyarat denyutan jantung. Kaedah kedua merupakan penyambungan perkakasan kepada komputer menerusi bicu mikrofon dan dipaparkan menerusi perisian MATLAB dalam bentuk isyarat denyut. Penghantaran tanpa talian meliputi implimentasi penghantar FM dan penerima FM. Akhir sekali, isyarat keluaran daripada penerima FM akan dikuatkan menggunakan penguat audio agar dapat didengar melalui pembesar suara.

ACKNOWLEDGEMENT

This project would not have been a success without the help and attention of many parties. I would like to take this opportunity to express my sincere gratitude to all those who have contributed in completing this project.

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Furthermore, I would like to thank the School of Electrical & Electronic Engineering for providing me with this wonderful opportunity to carry out the final year project. This project has exposed me to the current technology and also too increases my knowledge and skills in hardware and software implementation. I was also exposed to do a proper research in order to get a clear idea on the selected topic.

Finally, I wish to thank my parents and my friends who had supported and motivated me throughout the completion of this project.

Thank you,
SIVA KUMAR PALANIAPPAN
(25th FEBRUARY 2005)

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CHAPTER 1

INTRODUCTION

Training in cardiac auscultation is a core element of undergraduate medical student to understand the functioning of the heart. Eventually, recent studies have documented a remarkable decline in auscultatory skill. Therefore there is an interest in new ways to teach cardiac auscultation. In analogy to phonocardiography, an electronic system for simultaneous auscultation and visualization of murmurs was sought. For this purpose, an electronic stethoscope was linked to a laptop computer and software created to visualize heart sound and pulse. By implementing electronic stethoscope, this approach will greatly facilitate teaching (Woywodt, 2004). In this method, the teaching will be much easier and effective to both the student and the lecture. This heart beat tone serves as an effective diagnostic tool for a large class fetal stress provocation, such as hypoxia or deficiency of oxygen in the fetal blood. Audible heart sounds carry a lot of valuable information about the condition of the heart (Moghavvemi, 2003).

1.1 History

If we look the evolution of the stethoscope, various steps have been taken to produce a good heart sound detector gadget. Initially heart sounds were detected by placing the ear directly on the chest of the patient. Dr. Rene has take a next step by rolling up a sheet of paper and placed one end over the patient's heart and the other end over his ear. Dr. Laennec later replaced the rolled paper with a wooden tube (similar in appearance to a candlestick) which was called "stethoscope" from the Greek words "stethos" (chest) and "skopein" (to look at) (3M, 2005).

The design of stethoscopes changed little over the next 40 years or so, apart from the development of a differential stethoscope having two separate chest pieces, with tubing connected to each ear. Some work in 1894 by an Italian, Aurelio Bianchi, on a complex stethoscope incorporating a water seal, (which proved impractical in a clinical setting and was subsequently abandoned), resulted in a patent being filed by an engineer in the USA, R.C.M. Bowles, for a simple modern diaphragm chest piece. A growing acceptance of the need of both the bell and diaphragm, led Howard Sprague to design the first combination bell and diaphragm chest piece in 1926, which essentially remains with us to this day. The smaller bell was extended by a lever mechanism enabling easier and more accurate auscultation of infants and children. In 1961 another "electronic" stethoscope was developed by Amplivox, taking advantage of the smaller vacuum tube technology then available. This was intended purely as a teaching device, given its considerable weight and size. Again, microphone and amplifier technology, did not match the physicians' needs, and this proved to be a rudimentary device soon abandoned in favor of conventional stethoscopes (3M, 2005). Figure 1.1 shows evolution of the stethoscope.

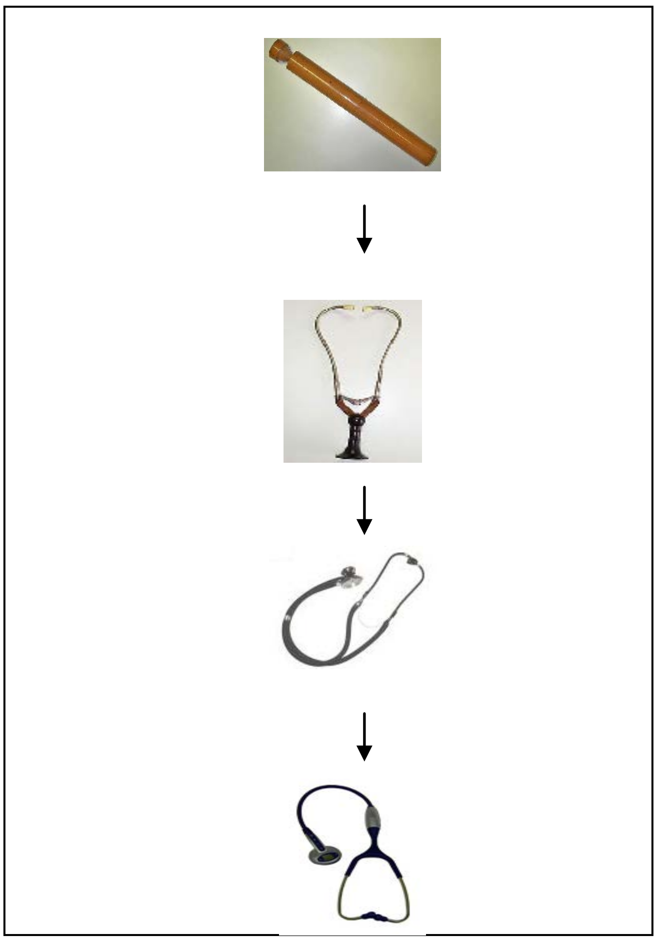

Figure 1.1: Flow of stethoscope evolution

Perhaps the most significant milestone occurred in 1961, when Dr. David Littmann, a cardiologist at West Roxbury VA Hospital, in Massachusetts, designed a streamlined, lightweight stethoscope, with a single tube binaural, which was available in both stainless steel and light alloy. Dr. Littmann had long been aware of the shortcomings of heavy and cumbersome stethoscopes currently available, and of the extraneous noise generated when the two tubes of the then existing models rubbed or snapped together. The Littmann combination stethoscope quickly became one of the most popular models in use, because of its light weight, flexibility and excellent acoustic properties (3M, 2005).

1.2 Project General View

Even though, the Littmann combination gives very good results, but the heart sound only can be heard by only one person. With the basic structure of the Littmann stethoscope, I have designed an electronic stethoscope whereby it can be heard by everyone including the patient. Teaching Stethoscope is involved in designing signal amplification, wireless transmission and computer display. Basically, Teaching Stethoscope project is consumed of small signal amplification whereby, signal is amplified by using a good stethoscope and instrumentation amplifier (INA126). This instrumentation is applied in the project so that the amplification of the signal is good enough to be displayed in the computer and heard through a speaker (Wynn, 1986). Most biological engineering needs op-amp as their main component to construct a project as signal amplification. TL081 is been choose in this project to implement the hardware design. Buffer is included as voltage follower to the circuit. This buffer is set as unity gain.

Noise reduction in heart sound is accomplished by applying filtering techniques. However, such filtering may mutate the original wave making difficult the interpretation of pathologies. To overcome this problem an adaptive filtering method able to filter heart sound without causing the loss of important information is proposed. (Sedra, 1998). Integrator and low pass filter is constructed by using op amp to reduce the noise generated by environment. Amplification of the audio signal is done by using TDA2003. Wireless transmission is implemented to hear the heart beat in a range of short distance by using FM transmitter-receiver. Receiver chip that have been used in this project is TDA7000. The output of the heart is displayed in to computer by using microcontroller 89C51 and MATLAB. The analog signal is covert to digital signal by using ADC0804 before proceeding to microcontroller. Finally the signal will be send to computer by serial communication using RS232 pin. This display is shown to monitor by using either by MATLAB or LABVIEW.

1.3 Objective and Scope

Studies on heart sound has been done long time ago. Different methods were used to get the signal from the heart. To learn about the methods and studies, we have to understand how the heart functions and produce the signal. Unexpected cardiac death and an expensive equipment to monitor heart beat pursuit me to design this project. The device designed through this project is a cheaper heart monitoring instrument which measures the electrical activity of the heart. This design done by me will be easy to be used by everyone. The objectives of this project are as follows:

- To understand, extract and analyze the appropriate characteristics to obtain the best results in designing a “Teaching Stethoscope”.
- To understand and learn the interface methodology of a microcontroller 89C51.

As we know heart problem has been on a rise tremendously in the world. Currently the only source for monitoring the heart beat is by visiting the doctor. The design of the “Teaching Stethoscope” would enable anyone to monitor their heart beat easily without the need to consult the doctor. The general function of this teaching stethoscope is to receive the heart signal which would then under go a few stages before it is delivered to the user through a monitor and a speaker.

1.4 Project Implementation

Initially, before beginning this project, I have gone through a brief introduction of heart function by referring biomedical books. This ensures me to know how to interpret the signal from the output display. Secondly, I have done a research in previous heart sound projects by going through journal and books. This step is taken, so that I can choose a best algorithm to be implemented in this project. In the designing process, I have done a rough sketch of component that will be used. It is very important to go through the specification of the chip datasheet that will be used. Every single chip has a different specification of usage and electrical characteristic. Each calculation is done separately to achieve the specification needed of every design. The designing is done through Orcad layout so that it will be easier for next process. Troubleshoot and testing is done in every single chip at the beginning stage to prevent any failure in the circuit. Output of each component is checked through the MATLAB scope, to see the quality of the signal that has been produced by every single chip. Furthermore, sound quality in each output signal of the component is tested by hearing through headphone after being amplified audio amplifier TDA2003. The transmitter and receiver are done at the end of the project. The whole will be checked at the end of the project. The flow or step taken to do this project is elaborate in figure below.

1.5 Report Organization

Five chapters are allocated for this project. For the first chapter, there will a brief introduction of a project. This chapter includes the background and main objective of the project. History of the stethoscope is stated in this chapter. In chapter two, there will more elaboration in theoretical studies and different methods of algorithm in doing the project. This chapter will discuss the function and characteristic of the heart in more detail. Element from the different method of studies is compared in this chapter. Chapter three is a methodology section. Discussion about the whole process of this project is done in this chapter. This will be including signal amplification, computer display and wireless transmission. Calculations of each design such as instrumentation amplifier, buffer, integrator, second order low-pass filter audio amplifier, microcontroller 89C51 and ADC0804 are shown in this chapter. Results and discussion is included in chapter 4. The quality of each signal is stated in this section by representing it in a figure 1.2. Last chapter of this project will be the calculation and future undertaking that should be taken while constructing this project.

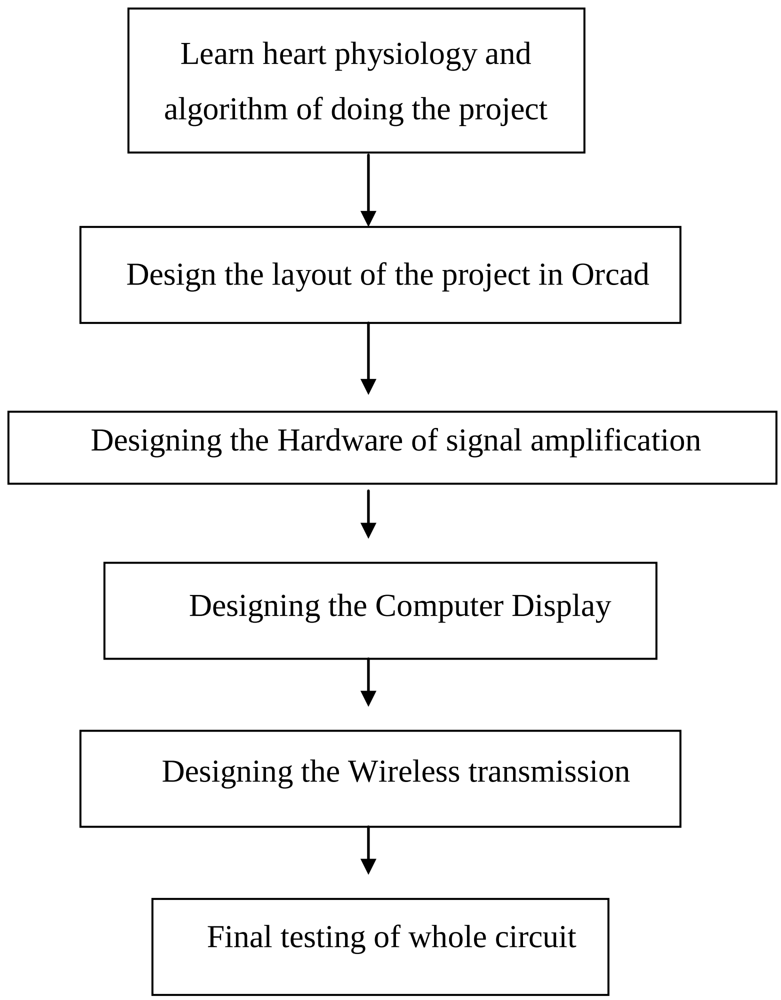

Figure 1.2: Flow Step on Project Work

CHAPTER 2

LITERATURE REVIEW

2.1 Development of the Heart

A human being's heart is about the size of the human being's fist. As the body develops, the heart grows at the same rate as the fist. There are several phases in the heart development. Initially, the heart is just a form of tube. Heart grows very fast until it needs more space. So it bends and twists back, forming a familiar shape. During the next phase, the two atria are partly separate but there is just one big ventricle. Third phase will begin when two atria are completely separate and the ventricles are jus beginning to separate. Finally, the ventricles separate completely and the heart is developed (Joseph, 1998)

2.2 Position

The human heart is located in the upper middle portion of the chest (thorax). Although many people believe that the heart is clearly on the left side of the body, it is actually a little more centered, with the lower tip pointed toward the left hip. About one-third of the heart lies to the right of the midline of the body; the rest lies to the left. This is the best location for detecting the best heart sound by using the stethoscope (Joseph, 1998). Figure 2.1 show the position of heart.

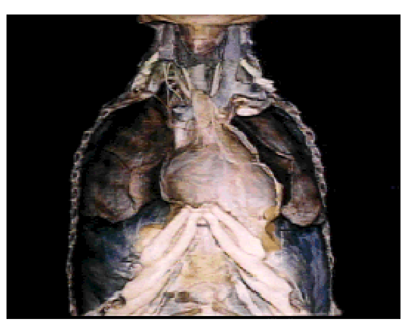

Figure 2.1: Position of Human Cardiovascular System

2.3 Characteristic

The size and weight of the heart vary form one individual to another. In most people the heart is approximately the size of their clenched fist. The average weight of the heart is on the order of 300 grams (g). By the end of a long life, a person's heart may have beaten (expanded and contracted) more than 3.5 billion times. In fact, each day, the average heart beats 100,000 times, pumping about 2,000 gallons (7,571 liters) of blood (Joseph, 1998).

2.4 Protection

The heart is a muscle encased in a sac called the *pericardium*. The double layer of tissue helps the heart stay in position and protects it from harm. The pericardium creates a lubricating fluid on its inside surface so that the friction between it and the heart wall is reduced, allowing the heart to beat freely within the walls of the sac. Besides two layers of pericardium, there is an *epicardium* and a *myocardium*, the main muscle tissue of the heart. This layer is represented in figure 2.2. The thick myocardium accounts for approximately 75 percent of the heart wall thickness (Joseph, 1998)

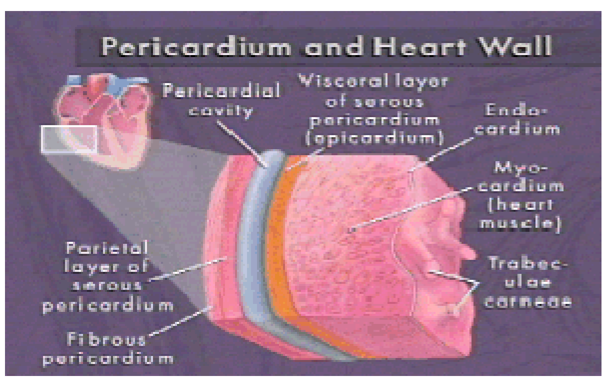

Figure 2.2: Pericardium and Heart wall

2.5 Division

The heart contains four chambers, which are used to form two separate pumps. Each pump consists of an upper chamber (atrium) and lower chamber (ventricle). The high pressure output side of each pump is the ventricle, so the *myocardium* thickness in the ventricular region is considerably greater than it is in the atrial region (Joseph, 1998).

2.6 Valve

There are four valves in the human heart. The valve between the right atrium and the right ventricle is known as the *tricuspid valve*. It gets its name from the fact that it is formed of three cusp-shaped flaps of tissue arranged so that they will shut off and block paasage of blood in the reverse direction *(from ventricle back to artrium).* These valves are attached at their bases to a fibrous strand of tissue ringing the opening between upper and lower chambers, and at their ends to objects called *chordae tendinae*. These structures are attached to the muscle tissue in the ventricle and keep the tricuspid valve closed as the right ventricular pressure builds up to force blood out of the heart into the pulmonary artery. The valve between the right ventricle and pulmonary artery also has a name reminiscent of its shape: *semilunar* (half moon) valve. It also consists of three flaps, but it lacks the chordae tendinae of the tricuspid valve. It prevents reverse flow of blood from the pulmonary artery to the right ventricle. Blood returning to the heart from the lungs must pass through the left atrium and the *bicuspid valve* to the left ventricle. This valve is formed of two flaps of cusp-shaped pieces of tissue. The last valve is the *aortic valve*. It is shaped similar to the pulmonary valve and function to prevent regurgitation of blood from the aorta back to the left ventricle (Joseph, 1998). Figure 2.3 shows the internal structure of heart.

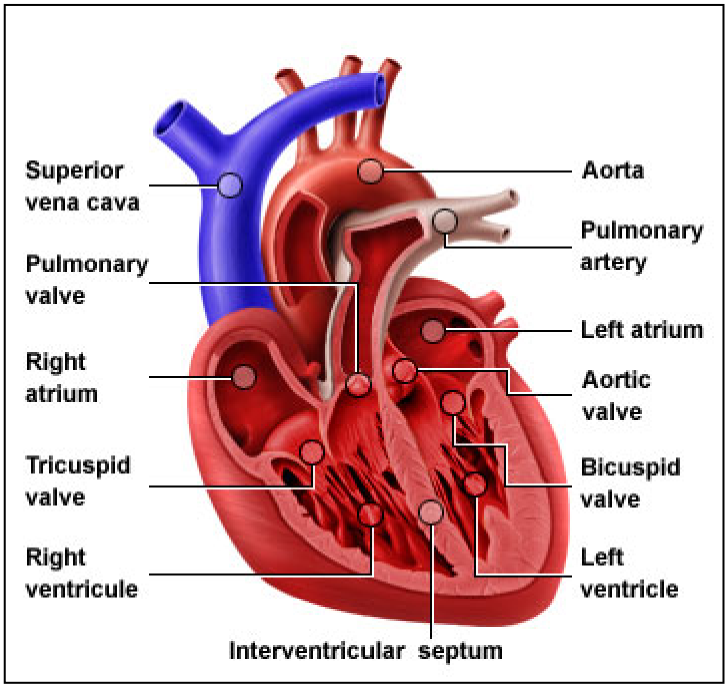

Figure 2.3: Internal Heart System

2.7 Heart Sound

There are various methods of way in detecting cardiovascular circulation. Many types of approaches have been taken such as by using ECG, stethoscope and many more for heart monitoring. ECG is done by implementing few electrodes in the patient body. Whereby, the electric impulse that been produced by the heart is detected by electrodes and displayed in electrocardiogram graph. Meanwhile, heart sound recording produce a heart beat sound by going through an electronic gadget. Heart sound monitoring is called as phonocardiography. The heart, like any mechanical pump, produces characteristic sounds as it beats. These are sounds the physician hears with a stethoscope. Basic heart sounds occur mostly in the frequency range of 20 to 200 Hz (Joseph., 1998) Certain heart murmurs produce sounds in the 1000 Hz region, and some frequency components exits down to 4 or 5 Hz. Figure 2.4 below shows a heart sound pulse that have detected through a electronic stethoscope from a young boy.(Woywodth, 2003).

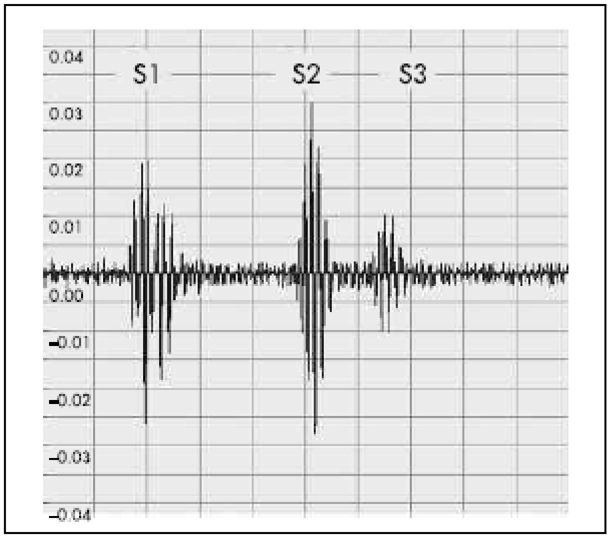

Figure 2.4: Heart Sound in a Young Healthy Subject

The first heart sound is generated at the end of atrial contraction, just at the onset of ventricular contraction. This sound is generally attributed to movement of blood into the ventricles, the atrioventricular (AV) valve closing, and the abrupt cessation of blood flow in the atria. It is the longest and the loudest of the four sound. At the onset of systole, ventricular pressure begins to increase and forces the blood within the ventricles toward the atria through the bicuspid and tricuspid valve. As these one way valve close, blood and the ventricular walls vibrates producing the S_1 sound. Therefore, S_1 sound is expected soon after the onset of the ventricular contraction, QRS of the waveform (Donald, 1990).

The second heart sound is generated the end of the ejection of the blood from the ventricles by the closure of the semilunar (half moon) valve which are aortic and pulmonary valves. At this point, blood from the ventricle is pumped into the arteries, arterial pressure exceeded the ventricular pressure, hence the one way valve are closing the pressure is reversed. These sounds have higher frequency components and the aortic valve sound is louder than the pulmonic valve sound (Donald, 1990).

The third sound corresponds to the cessation of ventricular filling, and the fourth sound is correlated to the atrial contraction. It is the weakest on of all the heart sounds. This last sound has very low amplitude and a low frequency component. Eventually, it is believed to be due to the oscillation of blood in the atria and atrial walls. It occurs immediately after the P-wave in the ECG (Donald, 1990). Heart sound waveform is shown in figure 2.5.

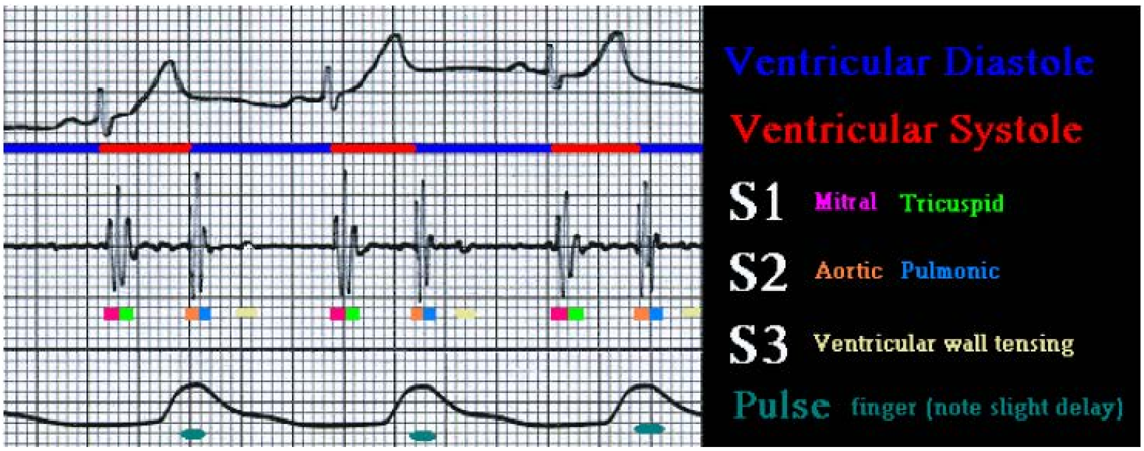

Figure 2.5: Timing of the heart sound in relationship to the electrical events detected in ECG waveform.

2.8 Theory of Stethoscope

Stethoscope is among the medical equipment that is widely used in the medical field to detect heart sound beside Electrocardiogram (ECG). A stethoscope generally consists of either a diaphragm or a bell that is attached to a long tube. This diaphragm or bell functions to capture heart sound. At the other end of the long tube is an earpiece that has an ear tube and ear tip that functions to drive the heart sound captured by the diaphragm or bell into the ears. Generally, the diaphragm is a better option compare to the bell (Welsby, 2003). The stethoscope bell could be used to detect breath sounds, but the diaphragm can detect normal breath sounds without enhancing lower pitched masking sounds. It can also be used to characterize and more accurately localize both normal and abnormal breath and heart sounds (Welsby, 2003).

As for the tube, it should be kept comfortably short to better hear high frequency heart sound components. It should also be long enough to allow a comfortable listening posture. Separate tubes starting at the chest piece can lead to each ear. The tubing should be relatively unyielding rather than elastic. The bore of the tubing should be small measuring one eighth to three sixteenths of an inch in diameter. Elastic, thin tubing walls with a large bore will decrease the amplitude of the audible heart sounds (Daniel, 2003). Figure 2.6 shows the properties of the stethoscope.

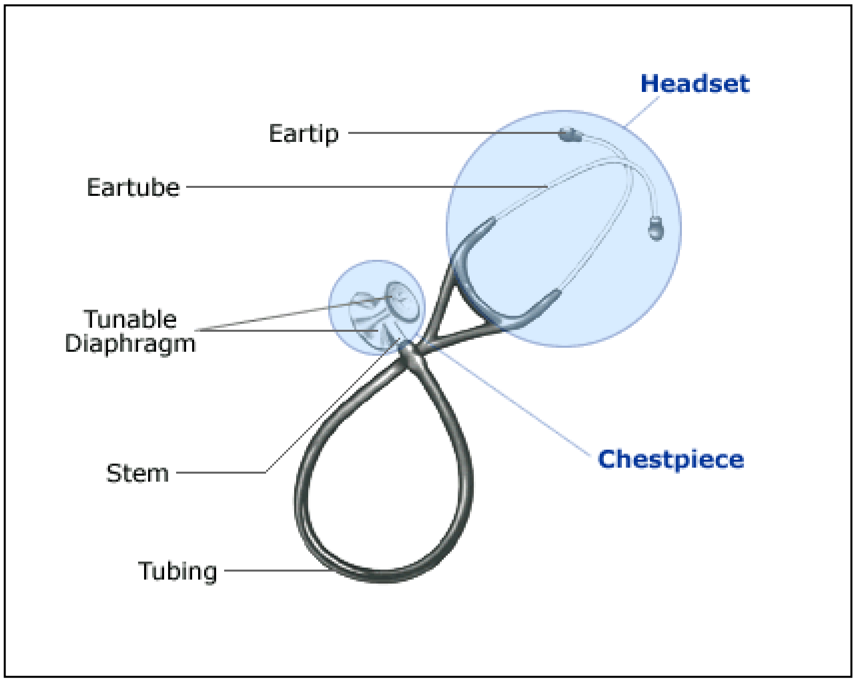

Figure 2.6: Stethoscope properties

One of the problems faced when using a stethoscope is the loudness in which the heart sound is heard through the stethoscope. This is caused by high ambient noise. High ambient noise levels and intermittent loud sounds from speech or electronic equipment interfere significantly with auscultation. Faint sounds are masked by louder sounds. The loud sound does not even have to coincide with the faint sound. The ear simply tunes to the louder sound and ignores the fainter sound. Proper auscultation technique requires listening to one thing at a time. Faint sounds require concentration. They should be listened to (without loud distractors) for a period of time that will (hopefuly) progressively decrease with experience. This allows the ear to become attuned to the full intensity of that particular sound level. Sometimes it also helps to close one's eyes (Daniel, 2003).

Besides the problem of hearing the heart sound due to high ambient noise, heart sound produce an incessant noise during lung sounds recordings. This noise severely contaminates the breath sounds signal and interferes in the analysis of lung sounds. To solve this problem the use of a wavelet transform domain filtering technique as an adaptive de-noising tool, can be implemented. The implementation of this wavelet-based filter in lung sound analysis results in an efficient reduction of the superimposed heart sound noise, producing an almost noise-free output signal. Due to its simplicity and its fast implementation the method can easily be used in clinical medicine (Hadjileontiadis, 1998).

2.9 Theory in Electronic Stethoscope

After considering the theory of stethoscope, this acoustic instrument has advantage on their robustness and ergonomic design. However, they are not ideal because it attenuate sound transmission proportional to frequency. The intensity of heart sounds and murmurs is generally faint with some sounds below the threshold of hearing. Eventually, to solve this problem, electronic stethoscope is been introduced to amplified the acoustic signal with more uniform frequency response (Marie, 1998). This signal can be amplified by using instrumentation amplifier. Instrumentation amplifier can be constructed by using simple op amp (type 741) circuit. Although it cost less, but this device gives remarkable results (Wynn, 1986). Figure 2.7 shows the design circuit of phonocardiograph by Wynn.

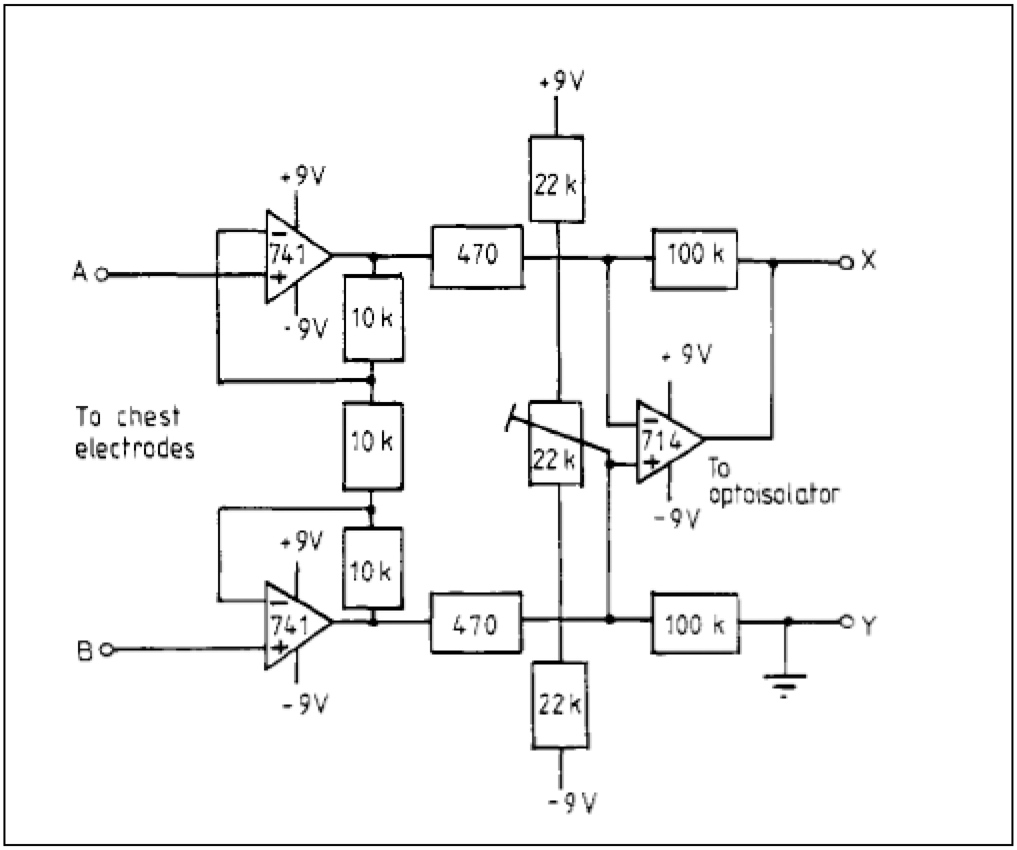

Figure 2.7: Phonocardiograph design by VT WYNN

However, it appears that these advantages are overcome by the sensitivity of the electronic stethoscopes to manipulation artifacts, electronic and ambient noises. Basically, real electronic circuit produces a certain level of inherent noise of its own. Meanwhile, there a few steps that can be taken to reduce this noise such as using negative feedback or any filer which follows the specification (Joseph, 1998). There are few methods of analysis the heart sound such as JTF spectrogram analyzer or heart sound waveform. The advantage of using JTF is that it can represent the frequency and the time in the same graph (Robert, 2003). Meanwhile, in a learning environment it is preferable to use heart plus waveform.

CHAPTER 3

METHODOLOGY

3.1 Project Flow

Initially this project is divided into three main parts. The three parts will be circuit designing in signal amplification, wireless transmission and computer display. Eventually in signal acquisition, components that involve are stethoscope, condenser microphone, instrumentation amplifier, buffer, integrator circuit and low pass filter. Designing the signal acquisition is the heart of the project. Every single element mentioned previously has to be taken into account while constructing the circuit in order to get quality results from the output. Most biological amplifiers contain op-amp. The design for a high-gain analog signal conditioning is achieved by using instrumentation amplifier. The system is constructed by cascading several op amp circuits to produce the desired gain. Unity gain buffers are used to ensure that the integrator draws no current from the amplifier. A great care is taken while constructing the op-amp to ensure that small DC offset voltages generated by the op amp circuit stages are removed from the signal path. While carrying out my project, I have noticed that noise is a major problem that reduces the quality of the sound that is generated by the heart. To eliminate it I have constructed integrator circuits and low pass filter. There are two ways in which signals can be corrupted in the system. First, interference noise occurs when unwanted signals are introduced into the system by outside source, e.g. power lines, transmitted radio and television electromagnetic waves. It is introduced in a power line from frequency range of 50Hz to 60Hz. Power lines noise can be a very difficult problem in biological monitoring since the frequency range is within the biological signal being measured. Among the solution is by using silver cored wire to minimize coupling effects. The second type of corrupting signal is called inherent noise. Inherent noise arises from random processes that are fundamental to the operation of the circuit's elements and can be reduced by good circuit design practice. Basically, this project is done for a teaching purpose whereby heart sound can be heard by the lecture and student through headphone at the same time in a wireless system. Heart sound is displayed to the computer by using microcontroller interface. The entire process of building the teaching stethoscope is displayed in the figure 3.1.

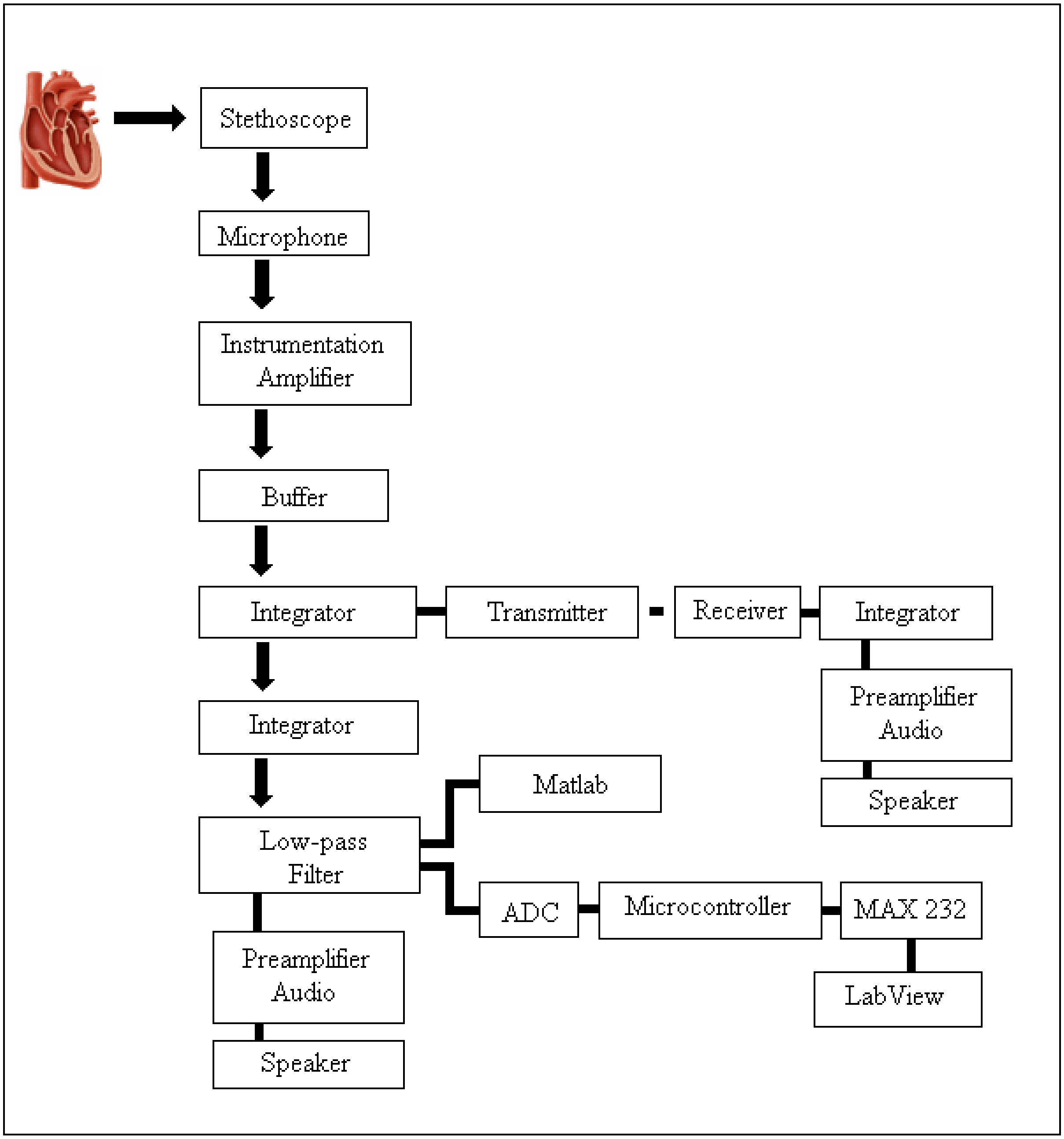

Figure 3.1: Flow process of the Teaching Stethoscope

3.2 Signal Acquisition Circuit Components

Signal acquisition circuit is constructed at the beginning stage of project. This designation section will be included biological amplification and noise filtering. Op amp is used to configure filter and amplifier design. Other mechanical structure such as microphone and stethoscope are also included in this part.

3.2.1 Microphone

One of the commonly used microphones is the “condenser” microphone. This microphone exploits electrostatic forces instead of magnetic induction. The “cone” in this case is a thin metallic membrane that forms one side of a parallel-plate capacitor (condenser is an old-fashioned term for capacitor). An incoming sound wave causes the membrane to vibrate and hence the capacitance changes. If the capacitor is charged through an external pull-up resistor, the time-varying capacitance will induce a time-varying current through the resistor and hence an AC voltage. Type of condenser microphone that has been used in this project is electret condenser. In this case the time-varying capacitance is used to modulate the gate voltage on a built in FET, which buffers and amplifier the signal. It is a basic transducer to detect heart sound and convert it to electric signal. There are many types of microphone in the market with different configuration. Below is the specification of the microphone that has been used:

- Unidirectional Black Electret
- Condenser Microphone Cartidge
- Series WM-65A103

Internal structure of microphone is illustrated in figure 3.2.

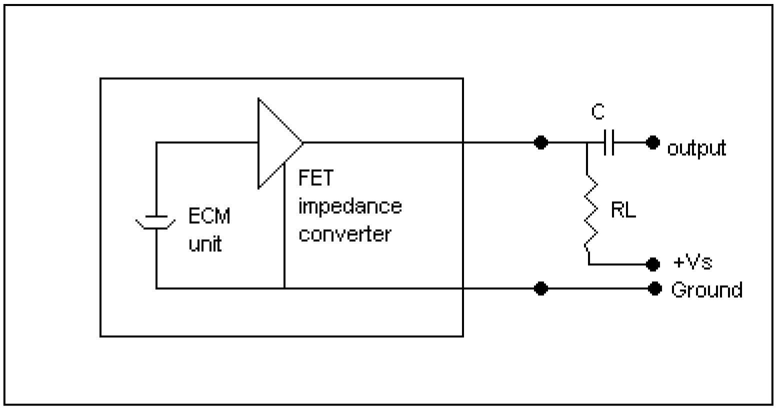

Figure 3.2: Microphone internal structure schematic

This condenser microphone is connected to the stethoscope by fixing it into the tube that is attached to the stethoscope. Meanwhile, the microphone is not only going to detect the heart sound but it also picks up noise from the surrounding area. This will indirectly, effect the reading. To get the better signal from the patients' heart, I have suggested the use of a stethoscope to capture the signal. This will then be detected by a microphone. Initially, before using the microphone to the heart, I tried to test the strength of the microphone using the oscilloscope. The signal was not in a clear form because no gain has been given. To make the microphone work a resistor of 2.2kΩ and 3V power is given. Capacitor is fixed to eliminate DC current. Pin connection to the microphone must be correct so that it can work well. The connections of microphone are showed in the figure 3.3.

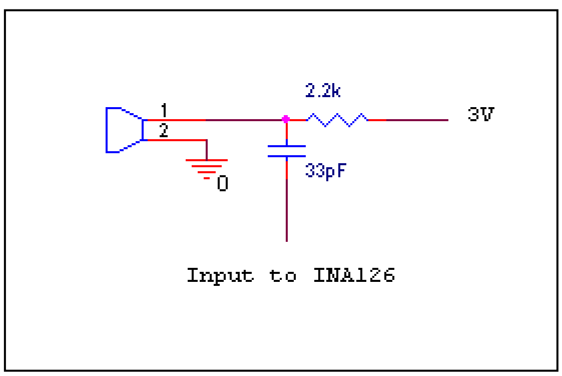

Figure 3.3: Microphone connection schematic

3.2.2 Stethoscope

There are few types of stethoscope in the market that can be purchased. It is one of the main gadgets to this project as to capture the heart sound from the body. Heart sounds are usually listened with a stethoscope. Rules for correct use of the stethoscope are as follows:

- Chest piece should be placed directly against the subject's skin.
- Position of the stethoscope will be in the left sided of the body because one-third of the heart lies to the right of the midline of the body and the rest lies to the left
- The chest piece should be applied with enough pressure to leave a slight depression when removed. However, excessive pressure over blood vessels may obstruct flow, causing loss of sound.
- If possible, try to make an air tight contact, sealed all around the perimeter of the chest piece.
- The finger holding the chest piece should remain straight and still. It is best to use the index finger to press on the stethoscope while holding the chest piece in place with thumb and middle fingers. Tubing should be in the palm of the hand holding the stethoscope and be extending towards the wrist.
- Stretching of the tubing should be avoided.

The figure 3.4 shows how I implemented the stethoscope in my project. As it can be seen in the figure, the microphone is attached to the stethoscope's tube.

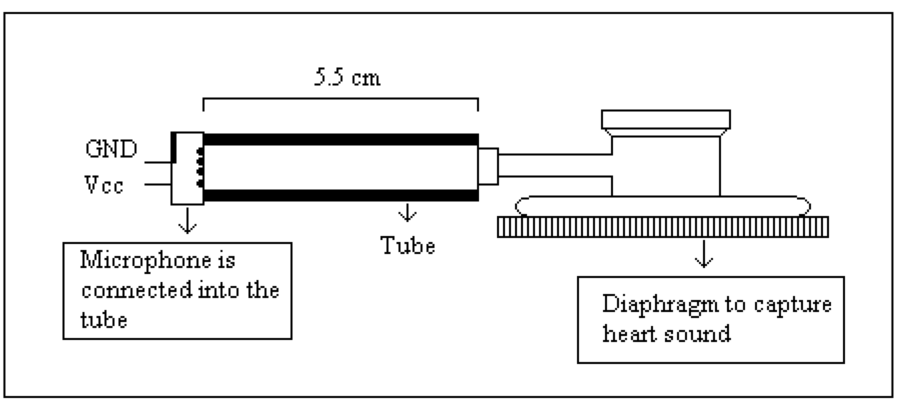

Figure 3.4: Microphone attached to the stethoscope

A good stethoscope captures a clear signal from heart and transmits it through a tube to be listened by the user. Every single part of the stethoscope is important. In my project, I have cut the stethoscope tube into a short length. It is because increase in the length of a stethoscope tube will decrease the pressure at the end of the hose as a result of frictional and other internal forces.

3.2.3 Instrumentation amplifier

Instrumentation amplifier is often used in biomedical application because they have extremely high input impedance, which means that they will draw very little current from the system that being measured. With instrumentation amplifier, it is also possible to obtain a high gain with low resistor values. Instrumentation amplifier also rejects common-mode signals, i.e. those signals that are most likely due to environmental noise rather than to some aspect of the signal that is being measured. A heart sound is amplified by using an instrumentation amplifier. Model type of instrumentation amplifier being used in this project is INA126. The INA126 are precision instrumentation amplifier for accurate, low noise differential signal acquisition. The positive input to the instrumentation amplifier is fixed to output of microphone, whereas the negative input is connected to ground. Below is the characteristic of the chip:

- Low quiescent current : 175µA/chan
- Wide supply range : ±1.35V to ±18V
- Low offset Voltage : 250µV max
- Low offset drift : 3µV/°
- Low noise : $35nV/(Hz)^{1/2}$
- Low input bias current : 25nA max
- 8-pin DIP, SO-8, MSOP-8 Surface-mount Dual: 16-pin DIP, SO-16, SSOP-16

Signal amplification gain can be set by changing the value of the R_G. This chip is capable to amplify a signal up to 10000 times. I have decided to use 1kΩ variable resistor to change the resistance according to gain that I need. Single version package have been used in this project with 8-pins. The figure 3.5 shows the schematic diagram of the instrumentation amplifier.

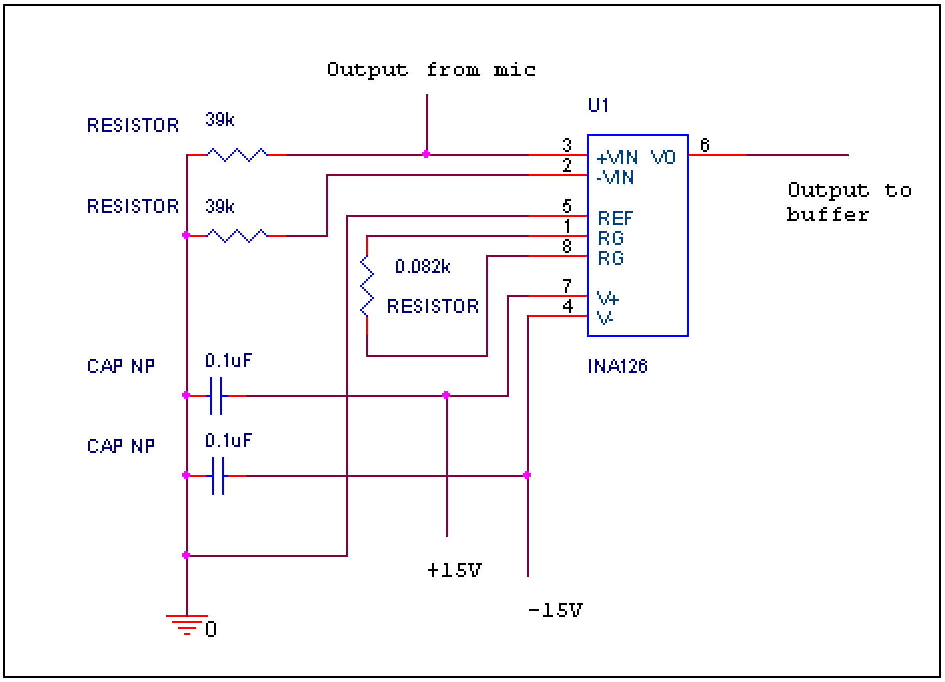

Figure 3.5: Instrumentation amplifier connection schematic

Setting the gain:

Gain is set by connecting an external resistor, R_G as shown below:

$$G = 5 + \frac{80k\Omega}{R_G} \tag{3.1}$$

Where, G = Instrumentation gain

R_G = Resistor gain

From the equation (3.1), gain is set as 1000,

$$1000 = 5 + \frac{80k\Omega}{R_G} \tag{3.2}$$

$$R_G = 80.4\Omega \tag{3.3}$$

For R_G I have used a *variable rheostat* to change the gain so that a good signal can be sent to the filter later. Capacitors are added in every source power because it's handling a noisy and high impedance power supplies.

3.2.4 Buffer

TL081 op-amps are used in designing the buffer circuit or voltage follower. In this type of circuit, G = 1. Unity buffers drive a current into a load without drawing any current from the input since $i_{in} = i_p$ and $i_p = 0$. This is a particularly important feature for physiological measurement such as heart sound detection. In the unity buffer, $v_p = v_{in}$ and $v_n = v_{out}$. Any current supplied to circuits connected to the buffer comes from within the TL081 op amp.

$$v_p = v_{in} \frac{R2}{R1 + R2} \tag{3.4}$$

Where, v_p = voltage output for buffer
v_{in} = voltage input for buffer
R_1 = Resistor 1 (buffer)
R_2 = Resistor 2 (buffer)

From the equation (3.4), $v_p = v_{in} = v_{out}$ since this is a unity buffer. Thus,

$$G = \frac{R2}{R1 + R2} \tag{3.5}$$

Where, G = Buffer gain

From the equation (3.5) substitute $R_2 = 10M\Omega$ and the gain is fixed as 1. Thus,

$$1 = \frac{10M}{10M + R2} \tag{3.6}$$

$$R_2 = 2.2k\Omega \tag{3.7}$$

The figure 3.6 shows the schematic diagram of the Buffer.

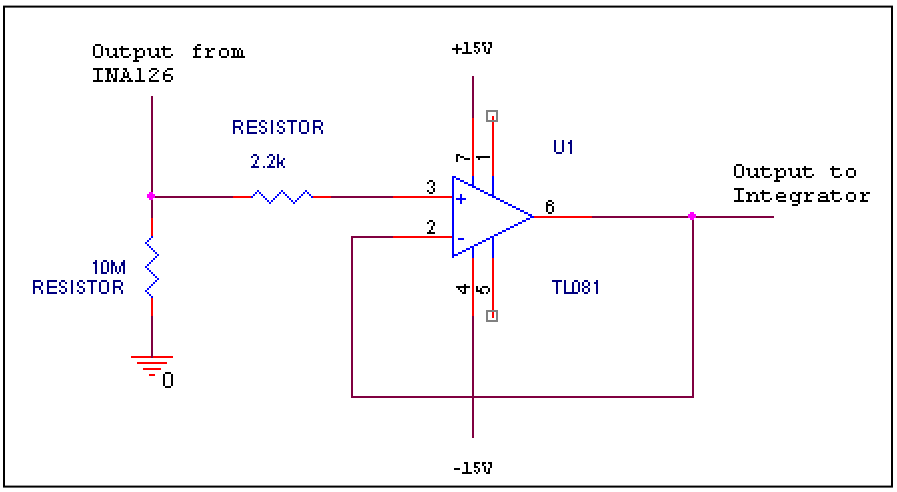

Figure 3.6: Buffer connection circuit

3.2.5 Filter

Filter is a device that passes electric signals at certain frequencies or frequency range while preventing the passage of others. Filter circuits are used in a wide variety of application. In the field of telecommunication, band-pass filter are used in the audio frequency range (0 kHz to 20 kHz) for modems and speech processing. High frequency band-pass filters (several hundred MHz) are used for channel selection in the telephone central offices. Data acquisition systems usually require anti-aliasing low-pass filters as well as low-pass noise filter preceding signal condition stages. System power supplies