ELECTRONIC STETHOSCOPE

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ABSTRACT

The stethoscope is one of the most simple and practical diagnostic tools used in medicine. Presently, two different types of stethoscopes available on the market are acoustic and electronic. Advantages of acoustic stethoscope are overcome by the sensitivity of the electronic stethoscope to manipulation artifacts, and electronic and ambient noises. Also, they do not take into consideration the sensitivity of the human ear, which varies significantly as a function of frequency. Therefore electronic stethoscope has become the demand in this new era of technology.

The purpose of this project is to design an amplifier circuit which is used in electronic stethoscope (biomedical instrumentation). This project is focusing mainly on the operational amplifier which is used for multiple purposes. Basically the whole process is trying to amplify a small signal into a larger signal with reduced noise so that the output signal will be greatly amplified. Operational amplifier is used for the purpose of amplifying the output signal. The output will be displayed in an oscilloscope to see the amplified signal. The designed circuit will be first simulated by using the OR-CAD software to analyze the output of the signal processing throughout each of the op-amp. Subsequently, we have to design the hardware of the circuit to design a functional circuit which is reliable with the theory. The expected output/results are an amplified signal with reduced noise.

ABSTRAK

Stetoskop adalah alat yang paling ringkas dan praktikal yang digunakan dalam bidang perubatan. Terdapat dua jenis stetoskop yang terdapat di pasaran iaitu, akoustik stetoskop dan elektronik stetoskop.Kelebihan akaoustik stetoskop diatasi dengan adanya elektronik stetoskop yang mempunyai kesensitifan yang tinggi terhadap gangguan suara. Stetoskop akaoustik juga tidak mengambil kira kesensitifan pendengaran manusia yang berubah mengikut perubahan frekuensi sekitaran. Oleh itu,elektronik stetoskop telah menjadi penumpuan orang ramai di era perubahan baru teknologi dunia kini.

Tujuan projek ini adalah untuk menghasailkan litar amplifier yang akan digunakan sebagai salah satu fungsi dalam elektronik stetoskop(instrumentasi bioperubatan). Projek ini secara asasnya fokus kepada operational amplifier yang akan digunakan dalam pelbagai tujuan di dalam litar. Secara amnya,keseluruhan proses dalam litar ini adalah bertujuan untuk mengamplify signal yang terlalu kecil kepada signal yang lebih besar yang mempunyai voltage yang lebih tinggi. Keluaran ataupun output yang telah diamplify akan dipaparkan dengan menggunakan osiloskop. Litar yang telah direka akan disimulate menggunakan software Or-Cad Pspice untuk manganalisis keluaran daripada setiap op-amp pada sambungan litar. Seterusnya, hardware untuk litar ini akan diateri dan disambungkan dengan power supply dan juga degupan jantung untuk menganalisa keluarannya. Keluran yang dijangka adalah signal yang telah diamplify dengan mengurangkan gangguan bunyi.

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LIST OF ACRONYMS

Symbol	**Description**
CMR	Common Mode Rejection
CMV	Common Mode Voltage
IMR	Isolation Mode Rejection
IMV	Isolation mode voltage
DC	Direct current
EMG	Electrocardiogram
ECG	Electroencephalogram
EMG	Electromyogram
NS	Nonstationary
STS	Short Term Stationary
JTFA	Joint Time-Frequency Analysis
CFT	Continuous Fourier Transform
STFT	Short Term Fourier Transform
MIC	Microphone
FET	Field Effect Transistor

CHAPTER 1

INTRODUCTIONS

1.1 Background

Electronic stethoscopes are one of the biomedical instruments that use the applications of advance amplifications to display the output signal in a display unit. Figure 1.0 below shows the anatomy of a conventional stethoscope. It does not have an electronically controllable circuit which can amplify the heartbeat signal to enable the output to be displayed in a display unit. My project is basically focuses on the amplification of the heartbeat signal using amplifier circuit designed by myself.

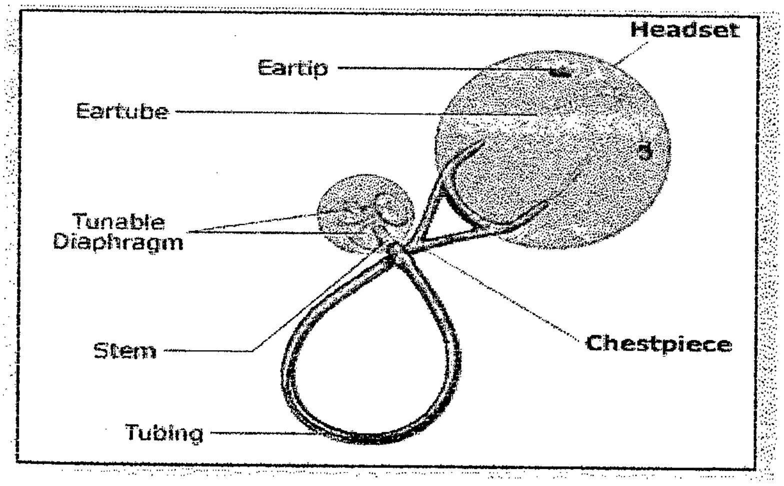

Figure 1.0 : Anatomy of a stethoscope

1.2 Objectives

Amplifier plays an important role in our everyday life. It has many applications. However amplifiers used in my designed circuit or project contributes to only selected application such as microphone pre-amplifier or buffer, isolating amplifier, unity gain amplifier and power amplifier.

The objectives of my project upon completion of this thesis are to :

- Get an amplified heartbeat signal as the output of my designed circuit.
- Enhance a deep understanding of the functions of amplifiers and other components used in current stethoscope features.
- Design and develop an amplifier circuit by using appropriate theories and calculation and finally to analyze the output by OR-CAD software and hardware testing.

1.3 Scope of study

Electronic stethoscope is a device that detects and analyzes the electrical activity of the heart. It comprises of processes such as to detect the heartbeat signal using a sensor, then to amplify the signal using amplifiers, subsequently the signal generated by the amplifier will be converted into a digital signal using ADC or microcontroller and it will be finally displayed using a display device.

However the scope of my project is the amplification part whereby amplifier is used to amplify the small signal of heartbeat. My studies during this research is based on the :

- Types of amplifiers and its applications
- Inter-relationship between biological and electrical signal

1.4 Problem statement

The stethoscope is one of the most simple and practical diagnostic tools used in medicine. Presently, 2 different types of stethoscopes are available on the market which is acoustic and electronic. The main advantages of acoustic stethoscopes are their robustness and ergonomic designs. However, they are not ideal because they attenuate sound transmission proportional to frequency and their frequency response shows maxima and minima at very specific frequencies due to tubular resonance effects, and differences in the transmission properties are observed between different models. Because the intensity of heart sounds and murmurs is generally faint with some sounds below the threshold of hearing, amplification of the acoustic signal with a more uniform frequency response has been introduced in electronic stethoscopes to solve the main limitations of acoustic stethoscopes.

However, it appears that these advantages are overcome by the sensitivity of the electronic stethoscope to manipulation artifacts, and electronic and ambient noises. Also, they do not take into consideration the sensitivity of the human ear, which varies significantly as a function of frequency. Consequently, the acoustic stethoscope is still the one mostly used today, even if several sophisticated designs have been patented for the construction of electronic stethoscopes during the last 20 years. An important aspect often excluded from the comparative evaluations of the performance of stethoscopes is the auscultatory ability of trained physicians and nurses.

An electronic stethoscope can be a considerable improvement over an acoustic stethoscope. It is more sensitive – to reduce the noise and to provide sound amplification.

1.5 Thesis outline

Chapter 1 explains the background of the project which is a reflected wave principal that is used to do this project, project objective, scope of the project and problem statement.

Chapter 2 discusses mainly about the theories and references considered before proceeding with my project.

Chapter 3 focuses on the methodologies used for the designing and development of my project . It gives a brief reviews on the design procedures as well as the testing procedures.

Chapter 4 exposes all the results obtained from both simulation and practical. Discussions are also included in this chapter to analyze the results.

Chapter 5 describes the conclusion of development of my project. This chapter also discusses the problems occurred throughout my project progress. Recommendation for future development of this project is also included in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 History

Initially heart sounds were auscultated by placing the ear directly on the chest of the patient. For the sake of convenience and propriety, in 1816 Dr. Rene Laennec invented first stethoscope by rolling up a sheet of paper and placing 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, which was called "stethoscope" from the Greek words "stethos" (chest) and "skopein" (to look at). The refinement of the stethoscope is an ongoing process and is reflected by the great variety of quality stethoscopes available today.

There were no significant developments to Laennec's device over the next decade or so. In 1829, Dr. Charles Williams improved the original Laennec stethoscope by dividing the instrument into two parts. This enabled the physician to stand in a more comfortable position, apply less pressure to the patient's chest, and also observe simultaneously "pulsations in the neck".

The design of stethoscopes changed little over the next 40 years, apart from the development of a differential stethoscope having two separate chest pieces, with tubing connected to each ear. A growing acceptance of the need of both the bell and diaphragm, led Howard Sprague to design the first combination bell and diaphragm chestpiece in 1926, which essentially remains with us to this day, albeit in a considerably developed form. Again, for an extended period until 1958, few developments were made until a new design by Dr. Aubrey Leatham, an English cardiologist, was revealed.

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. The Littmann combination stethoscope quickly became one of the most popular models in use, because of its lightweight, flexibility and excellent acoustic properties. The Littmann stethoscope continued to grow in popularity, and specialized models were added to the existing range.

[http://www.3m.com/us/healthcare/professionals/littmann/jhtml/history_of_scopes.jhtml, accessed in 2004, 3M]

2.2 Amplifier

An **amplifier** can be considered to be any device that uses a small amount of energy to control a source of a larger amount of energy, although the term today usually refers to an electronic amplifier. The relationship of the input to the output of an amplifier usually expressed as a function of the input frequency which is called the transfer function of the amplifier, and the magnitude of the transfer function is termed the gain. General characteristics of amplifiers are stated below :

2.2.1 Gain

This is usually measured in decibels (dB). The gain is equal to the output level divided by the input level.

2.2.2 Output dynamic range

This is the range usually quoted in dB between the lowest useful output and the largest useful output level. Since the lowest useful level is limited by output noise, this is quoted as the amplifier dynamic range.

2.2.3 Bandwidth and rise time

The bandwidth (BW) of an amplifier is usually defined as the difference between the lower and upper half power points. This is therefore also known as the −3 dB BW. Bandwidths for other response tolerances are sometimes quoted (−1 dB, −6 dB etc.).

2.2.4 Settling time and aberrations

Time taken for output to settle to within a certain percentage of the final value (say 0.1%). This is usually specified in oscilloscope vertical amplifiers and high accuracy measurement systems.

2.2.5 Slew rate

Slew rate is the maximum rate of change of output variable, usually quotes in volts per second (or microsecond).

2.2.6 Sine wave distortion

The properties of amplifier circuits distort the signal. This distortion comes in several forms including harmonic distortion and intermodulation distortion.

2.2.7 Noise

This is an undesirable thing that is the inevitable result of the electronics devices and components. It is measured in either decibels or the peak output voltage produced by the amp when no signal is applied.

2.2.8 Efficiency

Class A amplifiers are very inefficient, in the range of 10–20% with a max efficiency of %. Modern Class AB amps are commonly between 35–55% efficient with a theoretical maximum of 78.5%. Commercially available class D amplifiers have reported efficiencies as high as 97%. The efficiency of the amplifier limits the amount of total power output that is usefully available.

2.3 Instrumentation Amplifiers

There are three types of commonly used amplifiers for instrumentation and test equipment: single-ended and differential. Both of these amplifiers have benefits and drawbacks in the way they are used in measurement systems.

2.3.1 Single-ended

- Good for measurements between any point and chassis ground

- Susceptible to noisy environments
- Same signal common reference for multiple channels
- Cannot be used for "above ground" measurements

Single-Ended

A single-ended amplifier has only one input, and all voltages are measured in reference to signal common. In fact, single-ended is a misnomer, since the input voltage is measured relative to signal ground. With this amplifier, Vout is equal to Vin multiplied by the gain of the amplifier. This type of input is frequently used in devices such as oscilloscopes. A feature of single-ended amplifiers is that only one measurement point is needed. The following is a diagram for a single-ended amplifier:

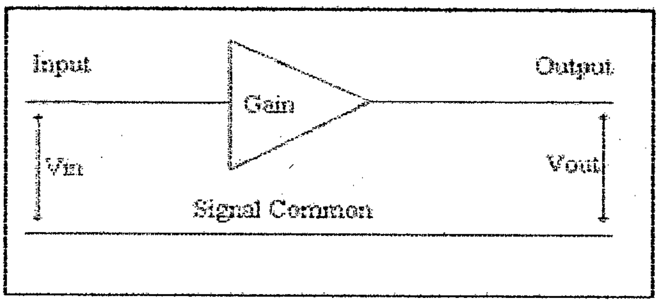

Figure 2.0 : Single ended amplifier

2.3.2 Differential

- Amplifier the difference between two points
- Less susceptible to noisy environments (CMR)
- Can be used for "above ground" measurements up to the CMV
- Some signal common reference for multiple channels
- Possible crosstalk with wide voltage differences between channels

Differential

A differential amplifier has two inputs, and amplifies the difference between them. The voltage at both inputs is measured with respect to signal common. The following is a diagram for a differential amplifier:

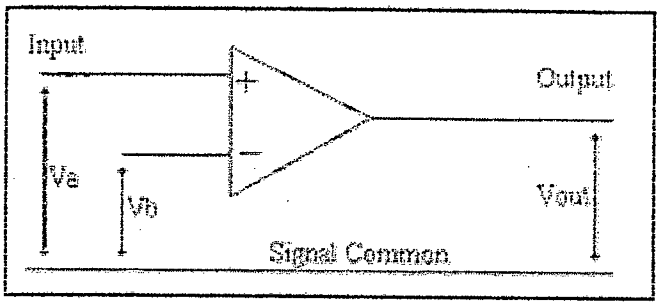

Figure 2.1: Differential amplifier

CMR=20log(CMRR)=20log(Gd/Gc)

The goal when designing such an amplifier is to make the CMR as high as possible. A higher CMR indicates a differential amplifier that is less susceptible to voltages common to both inputs (noise). Another benefit of a high CMR is the ability to accurately measure a small voltage difference between two points that are both at a higher voltage potential. Since CMR decreases as the frequency of a signal increases, it is usually specified at a particular frequency (i.e., 60 Hz).

Another important specifications associated with differential amplifiers is Common Mode Voltage (CMR). This is defined as the maximum voltage allowed at each input with respect to signal common. It is important to realize that the CMV of an amplifier can be much higher than the measurement range of that amplifier. Generally, a higher CMV allows an amplifier to be used in a wider range of applications.

Differential amplifiers are quite common, since they do not have the advantage of single-ended amplifiers. They are useful for "above ground" measurements, as long as the CMV of the amplifier is not exceeded. They are also useful in environments where there is potential noise. One of the drawbacks of the standard differential amplifier is that in a multi-channel system, signal ground is often the same for all channels.

2.3.3 Isolated

- Amplifies the difference between any point and iso-common
- Commons are isolated from chassis ground, earth ground and other commons
- Less susceptible to noisy environments (IMR/CMR)
- Can be used for "above ground" measurements up to the IMV/CM
- No crosstalk, even with wide voltage differences between channels

Isolated Inputs

An isolated input has a signal common (iso-common) that is isolated from the power supply for the analog circuitry. An additional feature is that in a multi-channel system, each channel's iso-common is independent and isolated from other channels. Isolated inputs can be either single-ended or differential, although a single-ended isolated input will have similar specifications to a differential one.

An isolated differential input is useful with DC bridges, where an excitation voltage must be supplied. With isolated amplifiers, the terms Isolation Mode Voltage (IMV) and Isolation Mode Rejection (IMR) are used interchangeably with CMV and CMR. Isolated single-ended amplifiers, for example, have the same noise reducing characteristics as a non-isolated differential amplifier. The following is a diagram for an isolated single-ended amplifier:

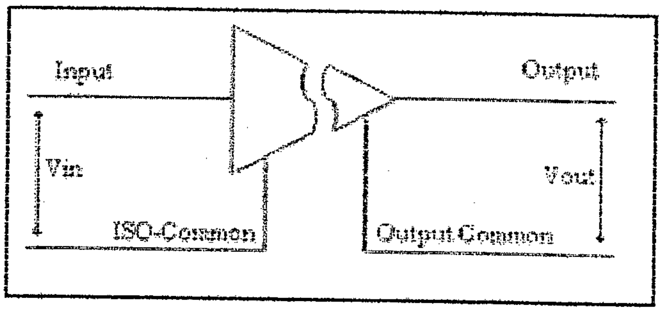

Figure 2.2: Isolated amplifier

As the diagram illustrates, the isolated common on the input of the amplifier is not referenced to the output common of the analog circuitry. In fact, the iso-common can actually be used for "above ground" measurements, up to the limitation of the CMV. In this respect, an isolated single-ended amplifier is very much like a standard differential one.

Many Astro-Med instruments make use of both transformer and optically-coupled isolated inputs, which offer such benefits as channel-to-channel isolation, noise reduction, and higher CMV in more sensitive ranges. With isolated amplifiers, the amplification stages are isolated from other circuitry. There is also no resistive path from the iso-common of any channel to chassis ground, no to any other iso-common.

2.4 Biomedical instrumentation

Instruments Used To Record Bioelectric Signals

Described below are the components of instruments we use to record bioelectric signals produced by the flow of ions (e.g. electrocardiogram ECG, electroencephalogram EEG and electromyogram EMG).

2.4.1 Electrodes

Electrodes are conductors that are located at the interface between a metallic and nonmetallic portion of a circuit. The metallic portion of a bioelectric circuit is a wire that leads either to an amplifier or a stimulator and the nonmetallic portion is most often the skin. Electrodes may be applied to the surface of the skin or inserted into the tissues. For example, needle electrodes may be inserted into muscles to record an EMG. Electrodes allow current to flow from the tissue to an amplifier and subsequently to a display device. Electrodes may also allow current to pass from an electrical stimulator into the tissue (e.g. paddle electrodes used in cardiac defibrillation). There are many different types of electrodes (e.g. plate, needle, disk etc) and their sizes and shapes depend on how they will be used.

2.4.2 Amplifiers

Biological signals are usually very small. An amplifier is used to increase the amplitude (size) of a biological signal so that it can be visualized on a display device. It doesn't change the actual signal coming from the tissue - it just changes the way you look at it. The magnitude of signal amplification is determined by the sensitivity (GAIN) control or vertical amplifier. For example, if the signal were to be increased in amplitude by 1000X (e.g.) from 1 millivolt to 1 volt (1000mV), the gain control must be set at 1000X.

On display devices with built-in amplifiers, the gain is often expressed in terms of volts (V) or millivolts (mV) per centimeter of pen (chart recorder) or per division of beam (oscilloscope) deflection. The larger the volts per centimeter reading, the lower the sensitivity. For example, a gain setting of 5 V/cm amplifies the incoming signal less than a setting of 1 V/cm. A second characteristic of an amplifier is that of coupling. This is the means by which the signal enters the amplifier. A signal may directly enter the amplifier without modification (DC coupling) or it may first pass through a capacitor (AC coupling). DC coupling is used for direct current signals or very low frequency signals (slow events). These are signals whose amplitudes fluctuate at a low rate or are constant.

An example of a low frequency signal would be the constant force exerted on a force transducer by a maintained muscle contraction. AC coupling is used for continuously fluctuating or higher frequency signals. When the amplifier is AC coupled, unwanted low frequency or DC signals are eliminated or attenuated (such as the background 60 cycle/sec signal generated by electrical appliances located in the laboratory). This process is called filtering. AC coupling would be used to record the electrocardiogram.

2.5 Theories

2.5.1 Biomedical and heart signal

A biomedical signal is a continuous (analog) time dependant record of a biomedical system [2]. Biomedical signals can be endogenous (natural) or exogenous (man-made). Heart sounds are endogenous signals because they are a byproduct of the natural function of the heart. Monitoring heart sounds with a sensor does not affect the signal. The heart sounds would be unchanged if they were being monitored or not. An x-ray image could be considered exogenous since the x-rays are artificially introduced by a machine and then are observed after interacting with the biomedical systems.

Heart sounds are nonstationary (NS) signals. Nonstationary signals change in time [2]. Heart sounds are synchronized with the heart rate, which varies