Palestine Polytechnic University

College of Engineering & Technology
Electrical & Computer Engineering Department

Graduation Project

Designing of Respiratory Monitoring System Using Impedance Plethysmography

Project Team

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By the guidance of our supervisor, and by the acceptance of all members in the testing committee, this project delivered to department of electrical and computer engineering in the collage of engineering and technology, to be as a partial fulfillment of the requirements of the department for the degree of B.Sc .

Supervisor Signature

……

Testing Committee Signatures

..... …….. ……..

Chief of the Department signature

…….

الإهداء

إلى تلك الأيادي البيضاء التي رعتنا منذ نعومة أناملنا إلى الآن ----------**أمي وأبي**.

إلى الشموع التي احترقت لتضيء حياة من حولها ----------**الأساتذة**.

إلى من جاد بدمه لهذا الوطن العزيز فلسطين ----------الشهيد.

إلى من أفنى زهرة شبابه و عمره خلف القضبان ----------الأسير.

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إلى من تجرع من كاس المرار و العذاب وفقدان الأحباء ----------الشعب الفلسطيني.

إلى من تاقت نفسه لافتراش الأرض و التحاف السماء ----------**اللاجىء**.

إلى كل من اتقى الله وحده و أمدنا بدعائه ----------**إخواني وأخواتي في الله**.

إلى كل نفس تواقة للعلم ابتغت من وراء علمها مرضاة الله وإعلاء كلمة التوحيد.

إهداء خاص

أخص بالإهداء والدي الحبيب (**أبو علي**)، الذي غاب عن الدنيا قبل أن يرى ثمرةَ جهده وتضحياته معي. وإني لأرجو الله أن يكون عملي هذا على مستوى عالٍ، ليعلم والدي أن جهده معي لم يذهب هدراً إن شاء الله.

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We would like to thank Palestine polytechnic university, college of engineering and technology, electrical and computer engineering department, also thanks to our parents who taught us to be good persons who work hard to achieve our aim, and for all their support and love all our life. We would like to thank every body shared in the success of our project; Thanks to Eng Abdullah Arman, for his suggestions and supervision during the establishment process of the project and for the reviewing of the report. Thanks to Eng. Fidaa Jaafreh, and assistant Rasmi saied Ahmad.

Abstract

Functionally, the respiratory system composed of an integrated set of regulated processes that include pulmonary ventilation (breathing) and gas exchange in the lungs. Under normal conditions, ventilation occurs spontaneously at the rate of 14 to 18 breaths per minute (bpm). Many people suffer from breathing disorders such as hyperventilation (characterized by an increase in pulmonary ventilation rate), hypoventilation (the decrease in pulmonary ventilation), and apnea (refers to the temporary cessation of breathing at the end of a normal expiration). Thus respiratory monitoring systems are one of the most important biomedical instruments in hospitals.

As respiration occurs, the impedance across the chest will change. Depending on this fact we will design system that can detect this variation in the chest. This system is called impedance pneumograph, which used in many neonatal respiration monitoring and apnea alarm.

The impedance measurement is made by introducing an electric current in the frequency range of 20-100 kHz into the volume conductor and measuring the corresponding voltage. The ratio of voltage to current gives impedance *Z*. Usually the DC value is eliminated and the impedance variation ΔZ is further examined. To eliminate the effect of the electrodes, separate electrode pairs for introducing the current and for measuring the voltage are usually used; the outer electrode pair is used for introducing the current and the voltage is measured across the inner electrode pair.

Using suitable software program, ΔZ can be displayed in PC, and apnea alarm can be designed.

خلاصة المشروع

يعتبر الجهاز التنفسي من الأجهزة الرئيسية و الحيوية للكائن الحي، حيث يقع على عاتقه القيام بالعديد من العمليات الحيوية الضرورية لبقاء الجسم على قيد الحياة. فمن خلاله تأخذ خلايا الجسم المختلفة غاز الاكسجين اللازم لانتاج الطاقة، وتتخلص من غاز ثاني اكسيد الكربون.

يتنفس الإنسان البالغ والسليم بمعدل ١٢ إلى ٢٠ مرة في الدقيقة، ويتغير هذا المعدل نتيجة عوامل مختلفة لعل أهمها تلك الأمراض المتعلقة بجهاز التنفس التي تؤدي إلى زيادة أو نقصان معدل التنفس، بل إن هناك حالات يحدث فيها انقطاع التنفس بشكل مؤقت، حيث تعرف هذه الظاهرة بال(Apnea)، والتي قد تؤدي إلى الوفاة إن لم يكن هناك متابعة فورية. لذلك ظهرت أهمية جهاز مراقبة التنفس بشكل عام.

نهدف في هذا المشروع إلى تصميم جهاز قادر على مراقبة معدل تنفس المريض، وإعطاء انذار في حالة انقطاع التنفس عند المريض إعتماداً على خاصية تغير مقاومة العضو نتيجة تغير حجمه (Impedance Plethysmography)، حيث نلاحظ تغير في حجم الصدرأثناء حدوث عملية التنفس، و بالتالي فإن مقاومة الصدر تتغير.

تتم عملية قياس مقاومة الصدر المتغيرة عن طريق تمرير تيار متردد ثابت، صغير المقدار، و عالي التردد (٢٠ – ١٠٠ كيلو هيرتز)، بحيث لا يسبب أي خطر على الإنسان. ومن ثم يتم إلتقاط الجهد في منطقة الصدر بلستخدام الكترودات مخصصة، توضع في مناطق معينة في الصدر، حيث يمثل هذا الجهد حاصل ضرب التيار الثابت بمقاومة الصدر، ويتم معالجة هذه الإشارة بحيث نحصل على المقاومة المتغيرة في نهاية الأمر.

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Chapter One
Introduction

1.1 Introduction

Without adequate respiratory activity, human life is under threat. A normal adult human has a respiratory rate of 14 - 18 breaths per minute at rest. Oxygen, O_2, enters the blood, and carbon dioxide, CO_2 is excreted through the alveoli.

Spontaneous respiration is completely dependent upon the rhythmic discharges of the respiratory centre in the medulla oblongata. Increases in ventilation are affected by increases in the rate and intensity of these discharges. A rise in the CO_2 or H concentration of arterial blood or drop in its O_2 concentration increases the level of respiratory centre activity.

Respiratory failure is difficult to predict and can become life threatening in a few minutes. Thus continuous monitoring of respiratory activity should be mandatory in clinical and high risk situations. Several non-invasive methods and devices provide information about respiratory rate or depth, or gas exchange. Methods are categorized into: volume and tissue composition detection, air flow sensing, and blood gas concentration. Our project aims to monitoring respiration in adults depending in first method (detection of movement, volume and tissue composition).

Muscle activity causes variation in thorax volume and pressure that give rise to variations in the venous return of blood to the heart. Variations in thorax pressure cause variations in air volume within the lungs, which, in turn, result in variations in transthoracic impedance. If we introduce constant current (at suitable frequency and

value) to the thorax, the corresponding voltage can be detected by suitable electrodes, the ratio of detected voltage to the introduced current gives the thorax impedance.

1.2 Project Objectives

The main objectives of this project are:

1- Design a non-invasive medical device that can be used for medical applications.
2- To use an impedance Plethysmography technique for respiration monitoring.
3- Designing an impedance Pneumograph device for adults.
4- Interface this device to the personal computer (PC).
5- Design diagnostic software, in order to draw ventilation signals (inspiration, expiration, breathing signal and ventilation rate signal), and then determine some breathing abnormal conditions such as apnea, hyperventilation, hypoventilation…etc.

1.3 What is the Importance of the Project?

Our project is very important, because it adds a new technique in the medical field through the Impedance Plethysmography. The importance of this device comes from the following:

1. It is safe.
2. Simple to use.
3. Test can be repeated.
4. Non-invasive technique.
5. The patient doesn’t require special preparation.

1.4 Literature Review

The study of this project depends on some ideas of other projects.

The first project prepared by RS Medical Monitoring LTD Company, under title Edema Guard Monitor (EGM). EGM is intended for detection of Pulmonary Edema (PED) before the appearance of its clinical signs. PED is the excessive accumulation of the liquid in the lungs caused by heart failure and some other diseases. The work of the monitor is based on noninvasive method of measuring lung's electrical resistance (across the right lung diagonally from upper side of the front to the downward of the back). The method is invented by Prof. Rabinovich and Dr. Shochat. From this project we obtained some information about the thoracic impedance, and the suitable type of electrodes.

The second project were done by Huda Abufarda, Fatima Battat, and Ayat Sha'aban. This project was done in Palestine Polytechnic University (PPU) to be the graduation project of this team. This project talks about Pulmonary Ventilation Monitoring and Diagnostic (PVMD), (technique used for monitoring breathing cycles, by attaching temperature sensor to the infant's airway). PVMD use mask contains temperature sensor, fixed on the infant's mouth and nose. From this project we obtained some information about respiratory rate and some Physiological information.

1.5 Time Plan

The chart in Figure (1.1) shows the sequence of our project’s work in the form of tasks each of which is assigned the week when it is supposed to be ready.

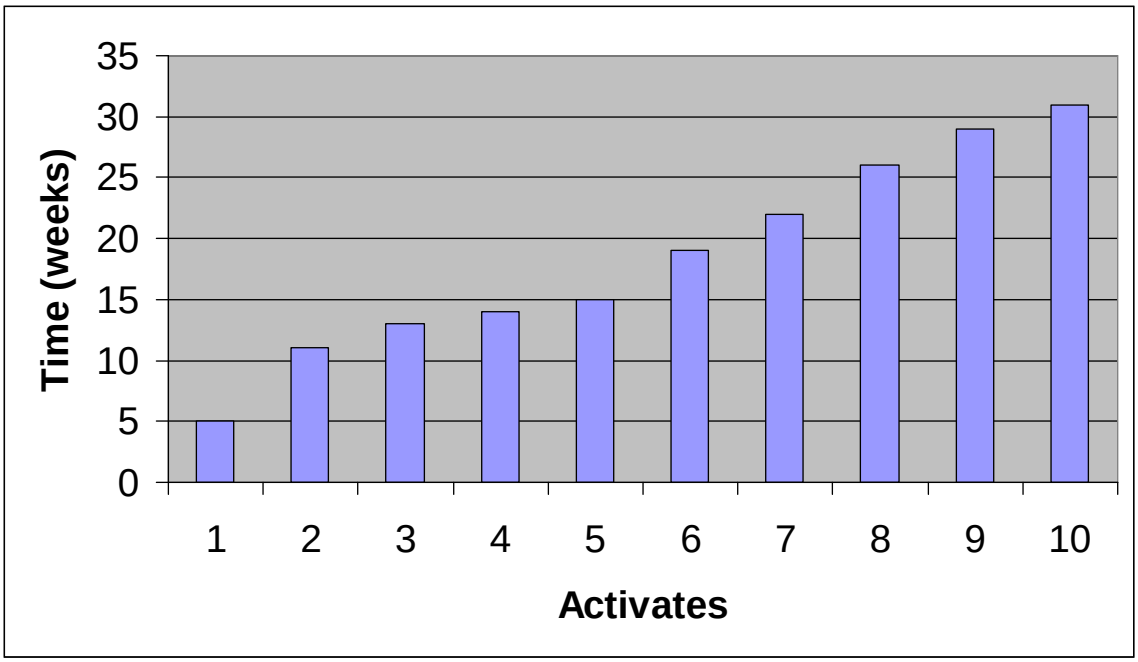

Figure 1.1: Time plan.

Table1.1: Time scheduling.

Time (Weeks)	Activates
5	Study Pneumograph Technology
11	Study Tissue Characteristics
13	Literature Review
14	Design Theory
15	Theoretical Report Ready
16	Discussion for Project Theory
19	Design the Schematic Block Diagram
22	Purchase Electronic Component for project
26	Build Hardware System
29	Design Software System
31	Testing System performance

1.6 Economical Study

This project needs the following accessories that are shown in table (1.2) with their salaries:

Table 1.2: Economical Study.

Component	Cost (SHEQALIM)
Transformers	50
Electrode Leeds	150
Diodes	10
Bridge Rectifier	10
LF355	10
LM308	5
UA741	20
Regulators	10
Resistors	20
Capacitors	20
Board	30
DAQ card	1800
PC	1800
Total cost = 3935	

Note:

As we see in the table the running cost will not exceed 100$, which indicate that this system is very economical.

1.7 Project Content

This report is divided into eight chapters; these chapters are described as follows:

Chapter one: In this chapter we describe the importance of the project, literature review, objectives, and economical study.
Chapter two: In this chapter we talk about respiratory system structure, mechanism of respiration, lung volumes, respiratory rate, and apnea.
Chapter three: This chapter includes respiratory transducers and instruments, and direct & indirect methods of sensing ventilation.
Chapter four: This chapter includes impedance Plethysmography theory & applications, thoracic impedance, and safety.
Chapter five: This chapter describes the general block diagram and the principle of operation and the hardware component that are used for this project.
Chapter six: This chapter describes the software program that are used to input data from hardware to PC and analysis the signals.
Chapter seven: This chapter includes results, and analysis of results.
Chapter eight: This chapter includes conclusions and future works.

Chapter Two
Physiology of Respiration

2.1 Introduction

Respiratory System, in anatomy and physiology, is a group of organs that deliver oxygen to the circulatory system for transport to all body cells. Oxygen is essential for cells, which use this vital substance to liberate the energy needed for cellular activities. In addition to supplying oxygen, the respiratory system aids in removing of carbon dioxide, preventing the lethal buildup of this waste product in body tissues. Day-in and day-out, without the prompt of conscious thought, the respiratory system carries out its life-sustaining activities. If the respiratory system's tasks are interrupted for more than a few minutes, serious, irreversible damage to tissues occurs, followed by the failure of all body systems, and ultimately, death.

While the intake of oxygen and removal of carbon dioxide are the primary functions of the respiratory system, it plays other important roles in the body. The respiratory system helps regulate the balance of acid and base in tissues, a process crucial for the normal functioning of cells. It protects the body against disease-causing organisms and toxic substances inhaled with air. The respiratory system also houses the cells that detect smell, and assists in the production of sounds for speech.

The respiratory and circulatory systems work together to deliver oxygen to cells and remove carbon dioxide in a two-phase process called respiration. The first phase of respiration begins with breathing in, or inhalation. Inhalation brings air from outside the body into the lungs. Oxygen in the air moves from the lungs through blood vessels to the heart, which pumps the oxygen-rich blood to all parts of the body. Oxygen then moves from the bloodstream into cells, which completes the first

phase of respiration. In the cells, oxygen is used in a separate energy-producing process called cellular respiration, which produces carbon dioxide as a byproduct. The second phase of respiration begins with the movement of carbon dioxide from the cells to the bloodstream. The bloodstream carries carbon dioxide to the heart, which pumps the carbon dioxide-laden blood to the lungs. In the lungs, breathing out, or exhalation, removes carbon dioxide from the body, thus completing the respiration cycle.

2.2 Respiratory System Structure

The organs of the respiratory system extend from the nose to the lungs and are divided into the upper and lower respiratory tracts. The upper respiratory tract consists of the nose and the pharynx, or throat. The lower respiratory tract includes the larynx, or voice box; the trachea, or windpipe, which splits into two main branches called bronchi; tiny branches of the bronchi called bronchioles; and the lungs, a pair of saclike, spongy organs. The nose, pharynx, larynx, trachea, bronchi, and bronchioles conduct air to and from the lungs. The lungs interact with the circulatory system to deliver oxygen and remove carbon dioxide [1].

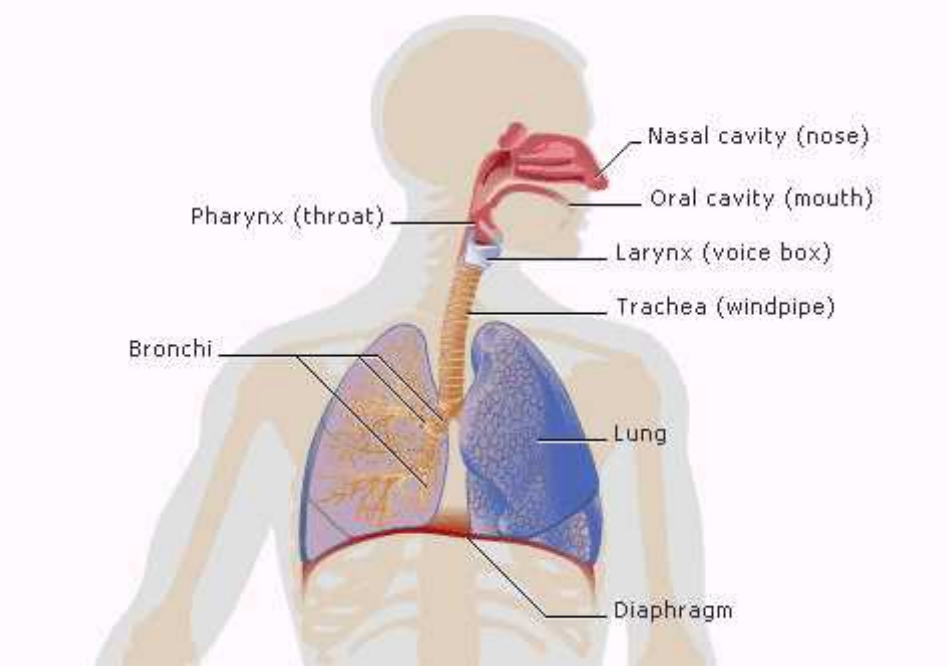

Figure 2.1: Respiratory System Structure [1]

2.3 The Mechanism of Respiration

The breathing is the process of moving oxygen-rich air into and out of the lungs. Respiration refers to all of the processes involved in getting oxygen to tissues, including breathing, diffusion of oxygen from the lungs to the blood, transport by the blood, and diffusion from the blood to tissues. Respiration is essential for aerobic respiration, the process within cells in which nutrients and oxygen are used to build the energy molecule adenosine triphosphate (ATP). In aerobic respiration, body cells use oxygen to metabolize glucose, forming carbon dioxide as a waste product that is exhaled.

Because body cells are constantly using up oxygen and producing carbon dioxide, the lungs work continuously. An adult normally breathes from 14 to 20 times per minute, but vigorous exercise can raise the rate to 80 breaths per minute. A

child’s rate of breathing at rest is faster than an adult’s at rest, and a newborn baby has a rate of about 40 breaths per minute [1].

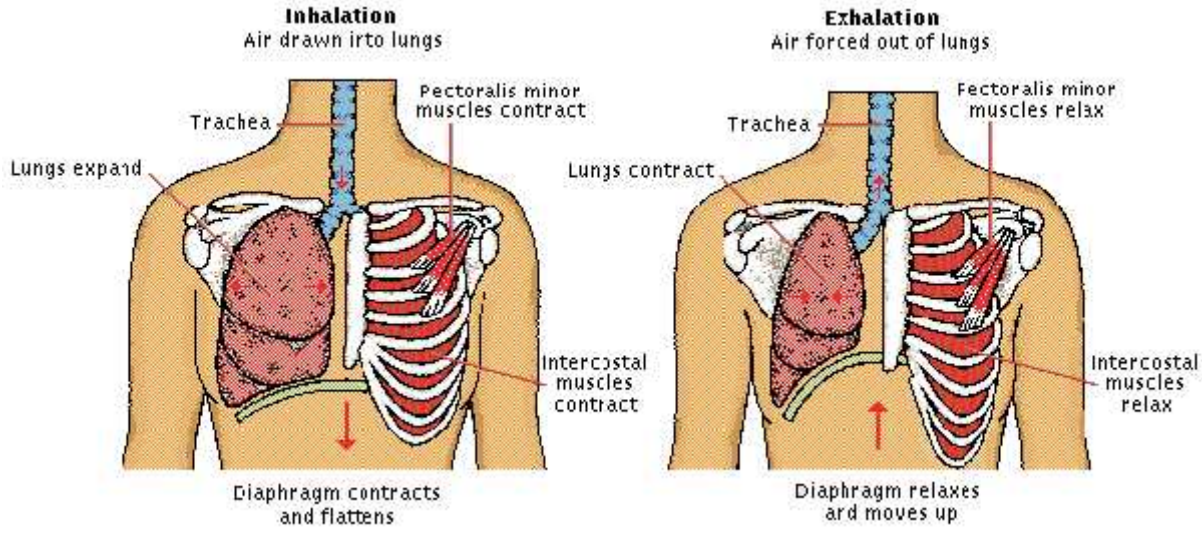

Figure 2.2: Respiration Mechanism [1]

The process of breathing is generally divided into two phases, inspiration and expiration. In inspiration, air is moved into the lungs. In expiration, air is forced out of the lungs. The lungs themselves have no muscle tissue. Their movements are controlled by the rib cage and the diaphragm. During inspiration the muscles around the rib cage contract, lifting the ribs upward and outward, and lowering the dome of the diaphragm until it forms a nearly flat sheet. As a result of these changes, the chest cavity expands. Because the lungs are attached to the chest cavity, they also expand. With the enlargement of the lungs, air pressure inside the lungs falls below the pressure of the air outside the body, creating a partial vacuum, and air from outside the body rushes into the lungs.

The amount of air normally taken into the lungs in a single breath during quiet breathing is called the tidal volume. In adults the tidal volume is equal to about 0.5 liters. The lungs can hold about ten times this volume if they are filled to

capacity. This maximum amount, called the vital capacity, is generally about 4.8 liters in an adult male, but varies from one individual to the next [1].

In expiration the muscles that lift the rib cage and lower the diaphragm relax. As a result, the rib cage and the diaphragm return to their original positions, and the lungs contract with them. With each contraction of the lungs the air inside them is forced out.

A person cannot hold the breath indefinitely, however. If exhalation does not occur, carbon dioxide accumulates in the blood, which, in turn, causes the blood to become more acidic. Increased acidity interferes with the action of enzymes, the specialized proteins that participate in virtually all biochemical reaction in the body. To prevent the blood from becoming too acidic, the blood is monitored by special receptors called chemo receptors, located in the brainstem and in the blood vessels of the neck. If acid builds up in the blood, the chemo receptors send nervous signals to the respiratory center, which overrides the signals from the cerebral cortex and causes a person to exhale and then resume breathing. These exhalations expel the carbon dioxide and bring the blood acid level back to normal.

A person can exert some degree of control over the amount of air inhaled, with some limitations. To prevent the lungs from bursting from over inflation, specialized cells in the lungs called stretch receptors measure the volume of air in the lungs. When the volume reaches an unsafe threshold, the stretch receptors send signals to the respiratory center, which shuts down the muscles of inhalation and halts the intake of air.

2.4 Lung Volumes

The volumes of air moved in and out of the lungs and remaining in them are matters of great importance. They must be normal so that a normal exchange of oxygen and carbon dioxide can occur between alveolar air and pulmonary capillary blood.

A graphic recording of the changing pulmonary volumes observed during breathing is called a spirogram (Figure 2.3).

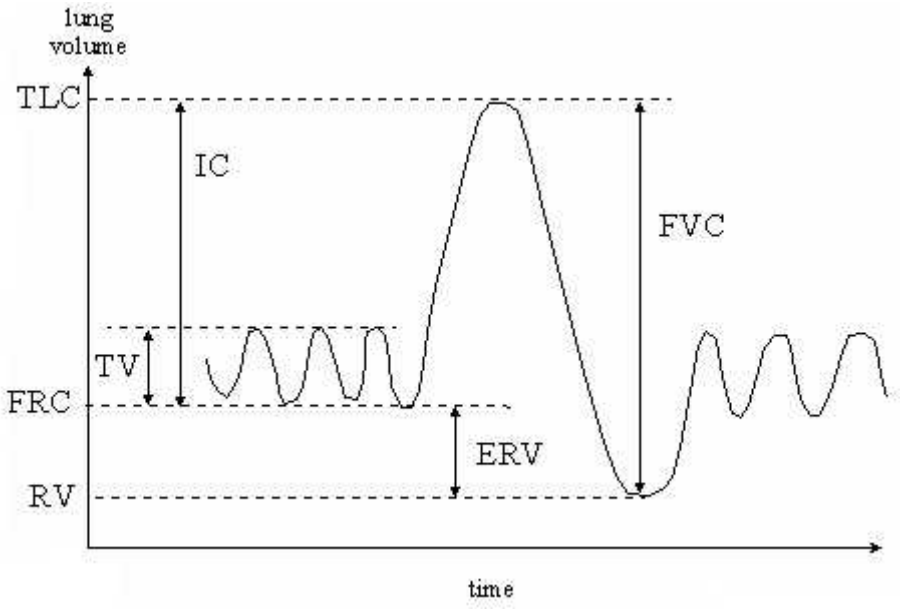

Figure 2.3: Spirogram [2]

1. Tidal Volume (TV=500 ml)

It is the volume that moved into or out of the respiratory tract during a normal respiratory cycle.

2. Inspiratory Reserve Volume (IRV=3000 ml)

It is the maximum volume that can be moved into the respiratory tract after a normal inspiration.

3. Expiratory Reserve Volume (ERV=1000 ml)

It is the maximum volume that can be moved out of respiratory tract after a normal expiration.

4. Residual Volume (RV=1200 ml)

It is the volume that remaining in the respiratory tract after maximum expiration.

5. Vital Capacity (VC=4500 ml)

VC = TV + IRV + ERV.

6. Inspiratory Capacity (IC=3500 ml)

IC = TV + IRV.

7. Functional Residual Capacity (FRC=2200 ml)

FRC = ERV + RV.

8. Total Lung Capacity (TLC= 5700 ml)

TLC = TV + IRV + ERV + RV.

Note: these lung volume values for a healthy adult male.

2.5 Respiratory Rate

The respiration rate is the number of breaths a person takes per minute. The rate is usually measured when a person is at rest and simply involves counting the number of breaths for one minute by counting how many times the chest rises. Respiration rates may increase with fever, illness, and with other medical conditions. When checking respiration, it is important to also note whether a person has any difficulty breathing.

2.5.1 Normal Findings

1. Normal respiratory rate in a healthy adult is between 12 to 20 breaths per minute.
2. Respiratory rhythm should be regular.

3. Respiratory depth should also be the same between breaths.

2.5.2 Normal Respiratory Rates by Age

1. Newborns: Average 44 breaths per minute.
2. Infants: 20-40 breaths per minute.
3. Preschool children: 20-30 breaths per minute.
4. Older children: 16-25 breaths per minute.
5. Adults: 14 to 18 breaths per minute [3].

2.6 Apnea

Apnea is a technical term for suspension of external breathing. During apnea there is no movement of the muscles of respiration and the volume of the lungs initially remains unchanged. Depending on the patency of the airways there may or may not be a flow of gas between the lungs and the environment; gas exchange within the lungs and cellular respiration is not affected.

Untrained humans cannot sustain voluntary apnea for more than one or two minutes. The reason for this is that the rate of breathing and the volume of each breath are tightly regulated to maintain constant values of CO_2 tension and pH of the blood. In apnea, CO_2 is not removed through the lungs and accumulates in the blood. The consequent rise in CO_2 tension and drop in pH result in stimulation of the respiratory centre in the brain which eventually cannot be overcome voluntarily [3].

Chapter Three
Respiratory System Measurements

3.1 Introduction

The respiratory system is responsible for bringing oxygen into the body and discharging waste carbon dioxide from the body, the principle of this system is covered in chapter two.

There are several different transducer used in respiratory measurements, although only a few different types of measurement are made. One class of instruments known as pneumographs is used to detect respiration, but these instruments do not deliver quantitative data about the system. These devices are often paired with a pneumotachometer (respiration rate meter) to perform monitoring jobs in intensive care units.

Instrument devised to quantitatively measure lung volumes are known as spirometers; both mechanical and electronic models are available.

Blood gases and CO_2 expired at the end of a normal tidal volume are also considered to be respiratory measurement.

3.2 Respiratory Transducers and Instruments

Respiratory instrument tend to be little more than extension of the transducers used to acquire the data from the subject. In some cases no more than a simple dc

amplifier is needed. It is, therefore, practically impossible to distinguish the transducers from the instruments.

There are direct and indirect methods of sensing alveolar ventilation, and breathing effort [4].

3.2.1 Direct methods

The method in which the sensor is coupled to the patient's airway, and measures the movement or other properties of the air transported into, and out of the lungs.

Various direct methods of sensing breathing effort, and ventilation, have been in use in the pulmonary physiology, and pulmonary function laboratories for many years, these involve the measurement of volume, flow, and composition of inspired and expired gases.

3.2.1.1 Carbon Dioxide Sensor

Expired air has a higher percentage of carbon dioxide than inspired air, and this can be sensed by placing an open ended tube at the nose or mouth, so that it samples the air entering, and leaving the airway. The sampled gas is transported along the tube to an instrument that contains a rapidly responding carbon dioxide sensor. This sensor detects the increased absorption of infrared radiation by carbon dioxide containing gas.

There is a delay in response of this instrument due to the time it takes the gas to be transported through the tube to the sensor; it is important to have rapid passage

through the tube. This can present some problems since the tube must be thin, flexible, and offers a relatively high resistance to the flow of gas.

3.2.1.2 Sound Measurement

Air passing over the end of an open tube, generates sound by producing local turbulence. A miniature microphone at the other end of the tube can detect this sound, and the level of sound is roughly proportional to the turbulence and, hence, the air flowing past the open end. This method can suffer from sensitivity to extraneous sounds other than the air passing the open ended tube.

3.2.1.3 Spirometer

Spirometer is an instrument for measuring air entering and leaving the lungs, used to assess pulmonary function. It is simply a device used for quantifying lung volumes and capacities by putting mouthpiece to the patient mouth as shown in the following figure.

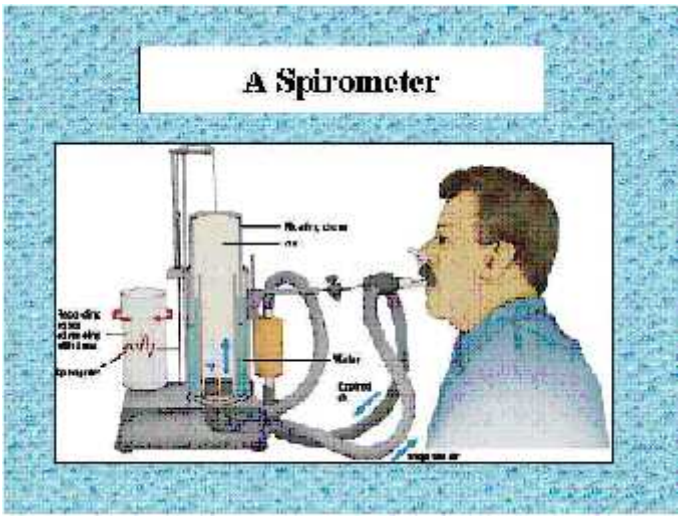

Figure 3.1: A Spirometer [5].

3.2.2 Indirect methods

In this method, the sensor looks at variables related to air movement but not at the air movement itself. Indirect methods involve no contact with the air way, or the air being moved into or away from the lungs. Usually, indirect methods; are noninvasive, and can be mounted on or near the body surface.

There are a wide variety of indirect sensors of ventilation; we will describe some of these various types of sensing systems.

3.2.2.1 Strain Gage Displacement sensors

Strain gages measure small displacements or strain in an electrical conductor, by measuring changes in its electrical resistance. A special type of strain gage consisting of a compliant, thin walled, rubber capillary tube filled with mercury.

This device can be placed on the chest or abdomen of an infant, breathing movements cause it to stretch and contract. By taping the ends of such a strain gage at different points on the chest or abdomen such that the gage is slightly stretched, the changes in electrical resistance of the gage can then be used to monitor infant breathing movements.

3.2.2.2 Motion Sensing Pad

Movements of neonates and infants can be sensed by a flexible pad that responds to compression by producing an electrical signal, when the infant is placed on top of the pad. The sensitive portion of the motion sensing pad structure is usually smaller than the overall size of the infant, and is located under the thoracic.

Infant breathing efforts result in periodic compression of the pad; this generates a periodic electrical signal related to the breathing effort. The major limitation of the motion sensing pad is its sensitivity to movements other than those related to respiratory efforts of the infant. Other body movements can be picked up by the sensor, and the device can even respond to movements that are not associated with the infant at all, such as an adult walking near, a heavy train, or even earthquakes.

3.2.2.3 Impedance Pneumograph

As respiration occurs, the impedance across the chest will change. The impedance pneumograph can detect this variation in the chest. The impedance measurement is made by introducing an electric current in the frequency range of 20-100 kHz into the volume conductor and measuring the corresponding voltage. The ratio of voltage to current gives impedance Z. Usually the DC value is eliminated and the impedance variation ΔZ is further examined. To eliminate the effect of the electrodes, separate electrode pairs for introducing the current and for measuring the voltage are usually used; the outer electrode pair is used for introducing the current and the voltage is measured across the inner electrode pair.

The output of the impedance pneumograph contains only rate data and the existence of respiration; hence its use in monitoring and apnea alarm devices.

3.3 Summary

After taking an idea about different types of Respiratory Instrumentations, you can see the limitations on each type, here, the importance of our device

appeared. Table 3.1 makes comparison between our device and the other devices discussed in the previous sections.

Table 3.1: Comparison between Spirometer, Impedance Pneumograph, and PVMD.

Spirometer	**Impedance pneumograph**	**Pulmonary Ventilation Monitor and Diagnostic**
Direct measuring and noninvasive.	Indirect measuring and noninvasive.	Direct measuring and noninvasive.
Work by using mouth piece in which the patient blown the air.	Work by attaching sensor on the chest. Uses the fact that the impedance across the chest of a subject changes as respiration occur.	Work by attaching temperature sensor (thermistor) on the patient mouth.
Mechanical device.	Electronic device.	Electronic device.
Used for quantifying lung volumes and capacities.	Monitoring device.	Monitoring device.
Less accuracy.	Good accuracy.	Good accuracy.

Chapter 4
Impedance Plethysmography

4.1 Introduction

Bioelectric tissue impedance measurements to determine or infer biological information have along history dating back to before the turn of the century. The start of modern clinical applications of bioelectric impedance (BEI) measurements can be attributed in large part to the reports by Nyboer [1970]. BEI measurements are commonly used in apnea monitoring, especially for infants, and in the detection of venous thrombus. Many papers report the use of the BEI technique for peripheral blood flow, and cardiac stroke volume.

BEI measurements can be classified into two types. The first and most common application is in the study of the small pulsatile impedance changes associated with heart and respiratory action. The goal of this application is to give quantitative and qualitative information on the volume changes (Plethysmography) in the lung, heart, peripheral arteries, and veins. The second application involves the determination of body characteristics such as total body fluid volume, inter- and extra-cell volume, and percent body fat. In this application, the total impedance is used and in some cases measured as a function of frequency, which is referred to as impedance spectroscopy.

4.2 Applications of Impedance Plethysmography

Electric-impedance Plethysmography is used to measure a wide variety of changes in the volume tissue. Electrodes placed on each side of the thorax provide

an excellent indication of rate of ventilation, but they give a less accurate indication of volume of ventilation.

Electrodes placed on both legs provide an indication of whether pulsations of volume are normal. If the pulsatile waveform in one leg is much smaller than that in the other, this indicates an obstruction in the first leg. If pulsatile waveforms are reduced in both legs, this indicates an obstruction their common supply. A clinically useful noninvasive method for detecting venous thrombosis in the leg is venous-occlusion Plethysmography.

Electrodes around the neck and around the waist causes current to flow through the major vessels connected to the heart. The resulting changes in impedance provide a rough estimate of beat-by-beat changes in cardiac output [6]

4.3 Thoracic Impedance

Figure 4.1 shows the cross-section of the thorax and its impedance.

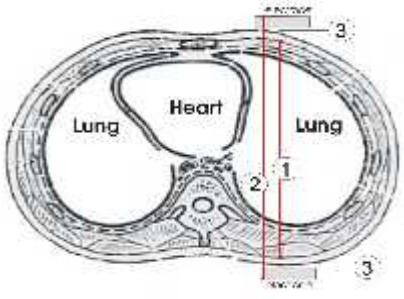

Figure 4.1: Cross-section of the thorax: {1- Internal Thoracic Impedance, (50-80Ω); 2-Trans-Thoracic Impedance, (1050-1280Ω), 3- Skin electrodes` impedance, each (500 - 600Ω)} [7].

4.4 Measurement Methods

Most single frequency BEI measurements are in the range of 20 to 100 KHz (these frequencies are high enough to avoid stimulation of tissue, electrode polarization, and problem associated with high skin Z values) using currents from 0.5 to 4 mA RMS. Currents at these levels are usually necessary to obtain a good signal-to-noise ratio when recording the small pulsatile changes that are in the range of 0.1 to 1% of the total impedance. The use of higher frequencies creates instrumentation design problems due to stray capacity.

Bioelectric tissue impedance measurements in the 50 to 100 KHz range have typical skin impedance values 2 to 10 times the value of the underlying body tissue of interest depending on electrode area. In order to obtain bioelectric tissue impedance values that can be used to give quantitative biological information, the skin impedance contribution must be eliminated. This is accomplished by using the four electrode impedance measurement method shown in Figure 4.2.

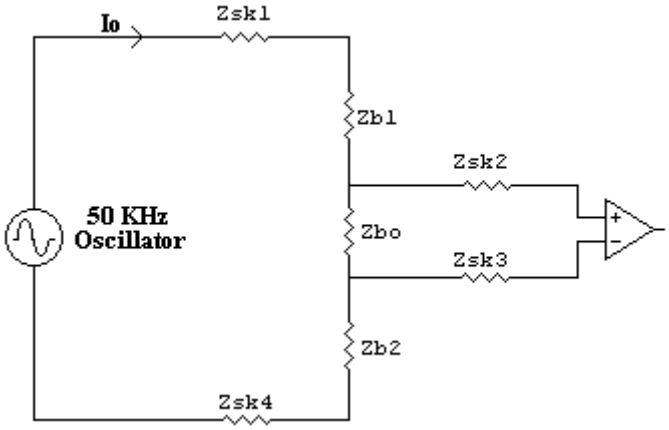

Figure 4.2: Four Electrodes Configuration [8].

Zbo is the internal section of tissue we wish to measure, it has a large steady part which is proportional to the magnitude of the tissue impedance (Zo) and a small (0.1 to 1%) part, ΔZ that represents the change due to respiratory activity. If we used

two electrodes to make the measurement, we would include two skin impedances (i.e., Zsk_1 and Zsk_4) and two internal tissue impedances (i.e., Zb_1 and Zb_2) which would make it impossible to estimate an accurate value for Zbo.

A constant current source supplies current, Io, to the outside two electrodes 1 & 4. This current flows through the skin and body tissue independent of tissue and skin impedance values. The voltage Vo is measured across Zbo with a voltage amplifier using electrodes 2 & 3. Assuming the output impedance of the current source is $>> Zsk_1 + Zb_1 + Zbo + Zb_2 + Zsk_4$ and the input impedance of the voltage amplifier is $>> Zsk_2 + Zbo + Zsk_3$, then

$$Zbo = Zo + \Delta Z, \quad Zo = Vo/Io, \quad \text{and } \Delta Z = \Delta Vo/Io$$

Where Zo is the non-time–varying portion of the impedance and ΔZ is the impedance change typically associated with the respiration. In order to obtain a signal representing ΔZ, Zo must be removed from Zbo and the signal amplified.

4.5 Respiration Monitoring and Apnea Detection

If the BEI is measured across the thorax, a variation of approximately 1 to 2 ohms per liter of lung volume change is observed, which increase with inspiration. The most common position of the electrodes for respiratory measurements is on each side of the thorax along the midaxillary line. The largest signal is generally obtained at the level of the xiphsternal joint although a more linear signal is obtained higher up near the axilla. [6].

The determination of apnea or whether respiration has stopped is one of the most widely used applications of BEI. When respiration stops, body movement stops, body movement ceases which eliminates the movement artifacts and then apnea can be detected.

4.6 Safety

The safety of bioelectrical instrumentation is assessed by two parameters. One is the aspect of electrical isolation from ground potentials for the subject. The second is the definition of what is a harmless current vs. frequency that can be deliberately introduced into the subject. There are few references that have explicitly established the standards for what is a safe subject current and frequency. Dr. L.A. Geddes and L.E. Baker in Applied Biomedical Instrumentation describe the threshold of electrical perception of alternating currents of varying frequency. At frequencies of 50 to 60 Hz (those used in power lines), nerve and muscle cells are stimulated. The sensation threshold is a few μA while pain and involuntary muscle contractions occur with much higher currents. Due to the large magnitude of cell membrane capacitance, the sensation and pain thresholds increases an order of magnitude as frequencies increase. Geddes and Baker determined that the pain threshold of an oscillator tuned to 50 KHz frequency would be approximately 40 milliamps. [9].

Chapter Five

Design Concept

5.1 Typical Biomedical Measurement Systems

A schematic representation of a typical biomedical measurement system is shown in Figure 5.1.The term measurement include image acquisition or the acquisition of other forms of diagnostic information.

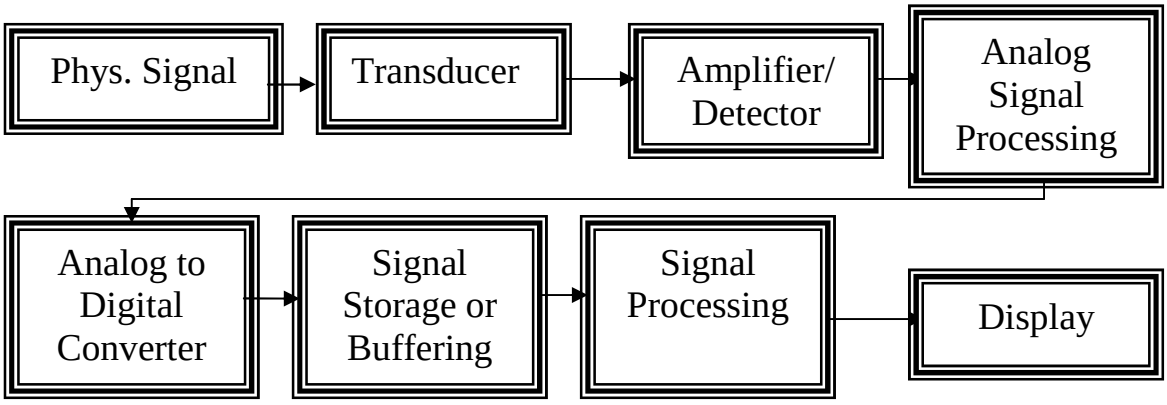

Figure 5.1: Schematic Representation of Typical Bioengineering Measurement System [10].

The physiological process of interest is converted into an electric signal via the transducer or electrodes. Some analog signal processing is usually required, often including amplification and low-pass (or band-pass) filtering. Since most signal processing is easier to implement using digital methods, the analog signal is converted to digital format using an analog to digital converter. Once converted, the signal is often stored, or buffered, in memory to facilitate subsequent signal processing. Alternatively, in some real -time applications, the incoming data must be processed as quickly as possible with minimal buffering, and may not need to be permanently stored. Digital signal processing algorithms can then be applied to the

digitized signal. These signal processing techniques can take a wide variety of forms and various levels of sophistication. Some sort of output is necessary in any useful system. This usually takes the form of a display, as in imaging systems, but may be some type of an effecter mechanism such as in an automated drug delivery system.

5.2 How System Work?

Our system aims to monitor the ventilation of an adult patient provided with alarm system, we observe that the ventilation frequency of an adult will not exceed 10 Hz, we also observe that an impedance pneumograph which we want to design should uses a 50 KHz sinusoidal oscillator, which will be calibrated to produce maximum current 40 mA. ΔZ signal will be monitored in the computer using suitable software program, which can also give apnea alarm after several seconds ranges between 10 to 40 seconds controlled by the operator.

Figure 5.2 shows the optimal block diagram for an impedance pneumograph. A low-voltage, high frequency (20 KHz to 100 KHz), ac signal is applied to the chest of the patient through surface electrodes of the same type as used in ECG monitoring. High-value fixed resistors connected in series with each electrode create a constant ac current source. This current flows through the skin and body tissue independent of tissue and skin impedance values. The signal is amplitude modulated by the internal section of tissue we wish to measure across the thorax, buffered by the buffers, amplified by a differential amplifier, and passed through band-pass filter centered on the carrier frequency, a narrow band pass filter is needed to pass the frequencies of interest and eliminates unwanted interference, leaving only the carrier waveform modulated by the tissue impedance signal. The signal emerging from the filters is then demodulated by an amplitude detector to remove the carrier. A low-pass filter following the detector removes residual carrier signal.

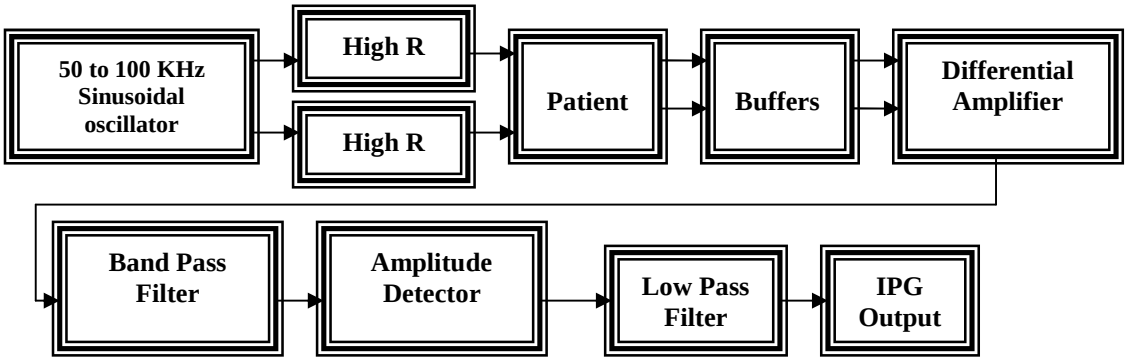

Figure 5.2: Optimal Block Diagram of Impedance Pneumograph (IPG).

5.3 Detailed Description

5.3.1 Sinusoidal Oscillator

5.3.1.1 Introduction

The oscillator is an electronic circuit with no AC input (having DC for biasing the active component), that can produce an ac output with specified frequency. In general, the oscillator is an amplifier with positive feedback, the feedback nature determines the specified frequency.

From the previous chapter, we conclude that 50 KHz is the most suitable frequency that can be applied in our project.

We designed several types of sinusoidal oscillators that can generate frequencies about 50 KHz, such as Phase Shift Oscillator, Colpitts Oscillator, and The Wien Bridge Oscillator, the sinusoidal signal which was created from the Wien Bridge Oscillator was the best.

5.3.1.2 The Wien-Bridge Oscillator

The Wien-bridge oscillator circuit can be viewed as noninverting amplifier configuration with the input signal fed back from the output through the lead-lag circuit.

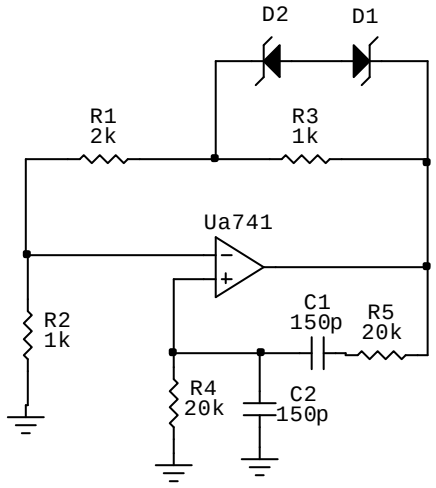

Figure 5.3: Wien-Bridge Oscillator Circuit [11].

The formula for the resonant frequency is

$$fr = \frac{1}{2\pi RC} \qquad [11].$$

Where $R_4 = R_5 = R = 20K\Omega$, and $C_1 = C_2 = C = 150pf$. This circuit produces frequency about 53KHz.

5.3.2 Constant Current Source

We designed this circuit by connecting the output of the oscillator with the input terminals of the center tap transformer, at the output terminal of the transformer we connected a 20KΩ Resistance as shown in figure (5.5), from this circuit, about 0.5 mA (r.m.s) current is obtained.

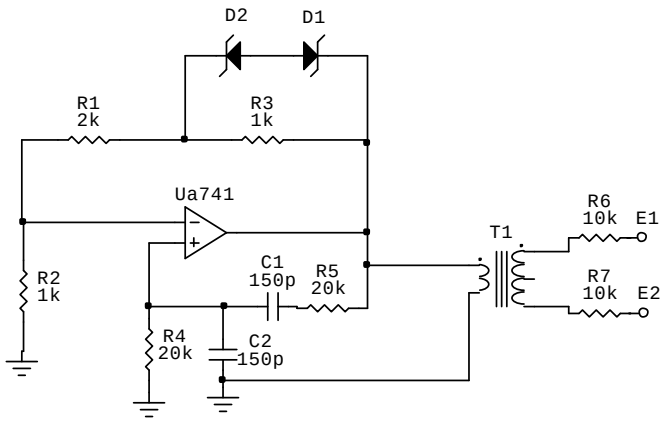

Figure 5.4: Constant Current Circuit

Where E1, & E2 are the outer electrodes.

5.3.3 Electrodes

In this project we used adhesive, disposable Ag-AgCl electrodes; these electrodes were easy to attach, and detected a strong Z signal.

5.3.4 Buffers & Differential Amplifier

At this stage we connected the inner electrodes (E3 & E4) with a buffer circuits which consist of Fet input amplifier (LF355) to allow absolute minimum loading on the electrode circuit. The output of the Fet amplifier was connected to the input of the Differential Amplifier as shown

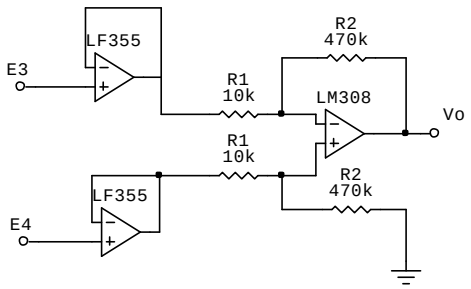

Figure 5.5: Buffers & Differential Amplifier.

In fact we designed several types of Differential Amplifier circuits, using several types of instruments such as AD620, LM741, and the above circuit. The best circuit that had least distortion on signal was the above circuit.

$$Vo = Av * (V2 - V1) \qquad [14]$$

$$Vo = \left(\frac{R2}{R1}\right)(VE4 - VE3)$$

$$Vo = 47 * (VE4 - VE3)$$

5.3.5 Active Band-pass Filter

The band-pass filter provides maximum gain (or minimum loss) to a specific frequency called the resonant, or center frequency (fc). Additionally, it allows a range of frequencies on either side of the resonant frequency to pass with little or no attenuation. The edges of the band-pass are identified by the frequencies where the response is 70.7 percent of the response of the resonant frequency (-3db).

The range of frequencies that make up the passband is called the bandwidth of the filter. This can be stated as

$$b\omega = f2 - f1.$$

Where f2 and f1 are the frequencies that mark the edges of the passband.

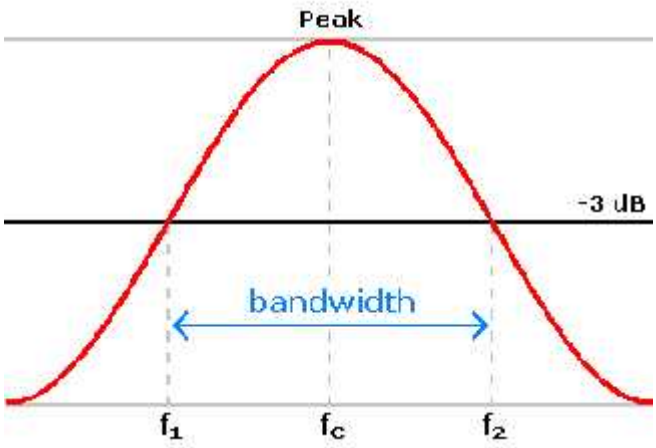

Figure 5.6: Band-Pass Filter Output [12].

The Q of the circuit is away to describe the ratio of the resonant frequency (fc) to the bandwidth (bω). That is

$$Q = \frac{fc}{bw} \qquad [13]$$

If the Qs exceed 20, a cascade filter should be used to avoid potential oscillation problems [13].

The band width of the modulated signal will be twice the frequency of the modulating signal (ΔZ) will be twice its frequency, (bω < 6Hz). The center frequency equal the carrier frequency -constant current frequency-, (fc = 50 KHz), we conclude that (Q >> 20). It is clear that we should design band-pass filter by using high and low pass filters in series, effectively forming a band-pass filter centered on the carrier frequency 50 KHz.

5.3.5.1 Low-pass filter

The following figure shows one of the most common implementations of the low-pass filter circuit. This particular configuration is called a Butterworth filter and is characterized by a very flat response in the passband portion of its response curve.

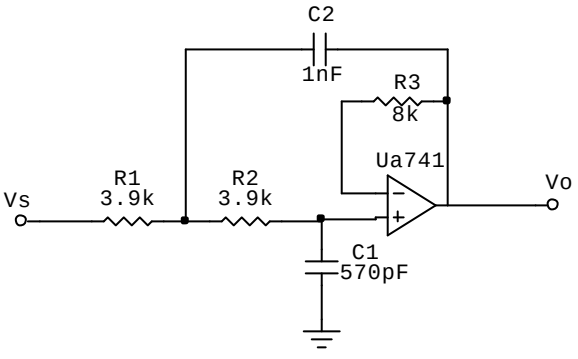

Figure 5.7: Low-pass filter circuit [13].

Ideally, a low-pass filter will pass frequencies from DC up through a specified frequency, called the cutoff frequency, with no attenuation or loss. Beyond the cutoff frequency, the filter ideally offers infinite attenuation to the signal. The cutoff frequency is defined as the frequency that passes with a 70.7 percent response. In the case of the circuit, the cutoff frequency can be computed by the following equation

$$fc = \frac{1}{2\pi R\sqrt{C1\,C2}} \qquad [13]$$

Where $R = R1 = R2$,

$R3 = R1 + R2$.

As shown in the figure we designed a low pass filter of about 54 KHz cutoff frequency.

5.3.5.2 High-pass filter

The following figure shows the schematic diagram of a high-pass filter circuit that provides a theoretical roll-off slope of 40 dB per decade. The circuit configuration is obtained by changing positions with all of the resistors and capacitors in the low-pass equivalent. As a high-pass filter, we will expect it to severely attenuate signals below a certain frequency and pass the higher frequencies with minimal attenuation.

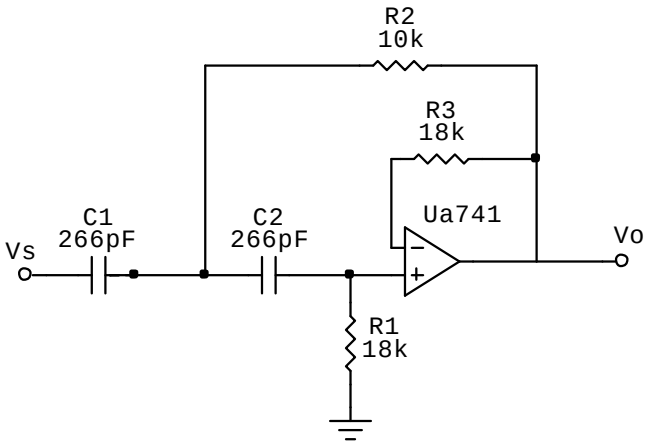

Figure 5.8: High-pass filter circuit [13].

The cutoff frequency for a high-pass filter is defined as the frequency that causes the output voltage to be 70.7 percent of the amplitude of signals in the passband. We can determine the cutoff frequency for the circuit by applying the following equation

$$fc = \frac{1}{2® C \sqrt{R1\ R2}} \quad [13]$$

Where C = C1 = C2,

$R_3 = R_1$.

As shown in the figure we designed a high pass filter of about 44 KHz cutoff frequency.

The output of the Band-pass filter in the system was a bout 4 Vp-p, 50 KHz, sinusoidal signal.

5.3.6 Precision Rectifier

When a high frequency, constant current source supplies current to the outside electrode, these current flows through the skin and body tissue independent of tissue and skin impedance. Giving the output voltage which given in the following equation

$$V_o(t) = (Z_{bo}).\cos \omega_c t$$

The output voltage $V_o(t)$, which is measured from the inside electrodes is in fact called amplitude modulated signal. Where Z_{bo} is the modulating signal. And $\cos \omega_c t$ is the carrier signal.

From the previous equation we conclude that when Z_{bo} change during breathing, the peak value of the $V_o(t)$ will change, so we designed a full wave rectifier in order to see the changes in the peak of the $V_o(t)$ clearly.

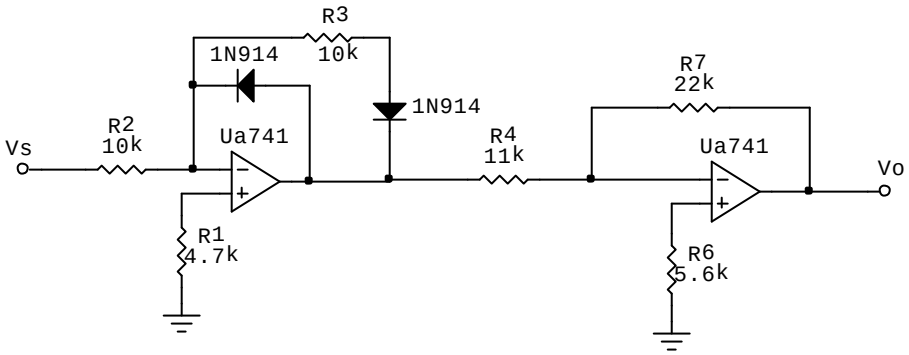

Figure 5.9: A Precision rectifier [14]

5.3.7 Power Supply

Since a power supply is a vital part of all electronic systems, and the operation amplifiers require both positive and negative power supply for proper operation of the circuit, we designed a +15V, -15V power supply, since the

Operational amplifiers which we used work optimally at these levels of voltages.

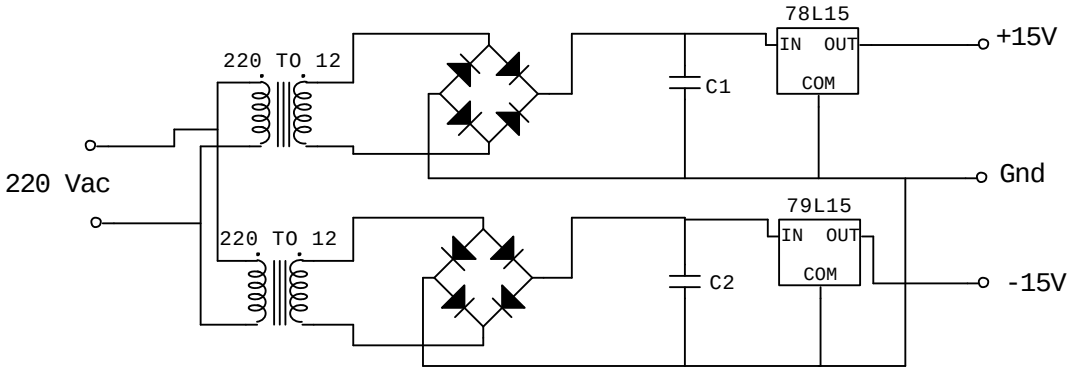

Figure 5.10: (+15V, -15 V) Power Supply

5.3.8 The DAQ (NI_PCI 6034E)

Figure 5.11: The DAQ card.

The NI 6034 DAQ uses the E series technology to deliver high performance, reliable data acquisition capabilities. This card is used in different applications such as:

- Continuous high-speed data logging at up to 200kS/s.
- Externally timed and/or triggered data acquisition.

- High-voltage and sensor measurements (when used with signal conditioning).
- High-channel-count system scalability with RTSI bus.

The NI 6034E card has many important features such as:

- This card has 16 analog inputs at 200kS/s, with 16 bit resolution.
- 2 analog outputs, each with 16-bit resolution.
- 8 digital input/output lines which are compatible with both 5V TTL and CMOS.
- Two 24-bit counter/timer, with 20MHz frequency.
- Digital triggering.
- 4 analog input signal ranges.

Chapter Six
Software System

6.1 The "LabVIEW" software

The "LabVIEW" which is an abbreviation of (Laboratory Virtual Instrument Workbench) is a full-featured graphical programming language with all the standard features of a general-purpose programming environment such as data structures, looping structures, and event handling. LabVIEW also has a built-in compiler that compiles all code at edit time. However, unlike other general-purpose programming languages, LabVIEW is specifically designed for engineers and scientists and has built-in tools to meet their needs. These high-level functions, assistants, and tools make LabVIEW much more than a programming language.

National Instruments (NI) LabVIEW is a graphical development environment for creating flexible and scalable design, control, and test applications rapidly and at minimal cost. With NI LabVIEW, engineers and scientists interface with real-world signals, analyze data for meaningful information, and share results through intuitive displays, reports, and the Web. Regardless of experience, LabVIEW makes development fast and easy for all users.

National Instruments LabVIEW delivers a powerful graphical development environment for signal acquisition, measurement analysis, and data presentation, giving the flexibility of a programming language without the complexity of traditional development tools, and it also uses dataflow programming, where the flow

of data through the nodes on the block diagram determines the execution order of the VIs and functions. (VIs are LabVIEW programs that imitate physical instruments).

So the LabVIEW can perform the following functions:

- Acquiring: NI LabVIEW is an open environment designed to make interfacing with any measurement hardware simple. With interactive assistants, code generation, and connectivity to thousands of devices, LabVIEW makes gathering data as simple as possible.

- Analyzing: LabVIEW has more than 500 built-in functions designed specifically for extracting useful information from any set of acquired data and for analyzing measurements and processing signals.

- Presenting: LabVIEW provides tools for data visualization, user interface design, Web publishing, report generation, data management, and software connectivity.[15]

6.2 Measurement Device

The continuous monitoring of the respiration was measured with an impedance Pneumograph system. This device detect the variation of the chest Resistance occurs during breathing by transmitting a high frequency, sinusoidal current with specific peak to the patient chest, the corresponding sinusoidal voltage drop will be detected, The peaks of this voltage will vary during respiration.

The detected voltage will transfer to the PC in order to process it using LabVIE program which can monitor this signal, and can measure the peak to peak value of it.

6.3 Signal Processing Algorithm

The signal processing algorithm aims to monitoring the sinusoidal signal produced by the Band-pass filter, measuring the peak to peak value of it, monitor the variation of the peak to peak value of it, and finally to check the apnea and give alarm if the apnea occurs for specific time.

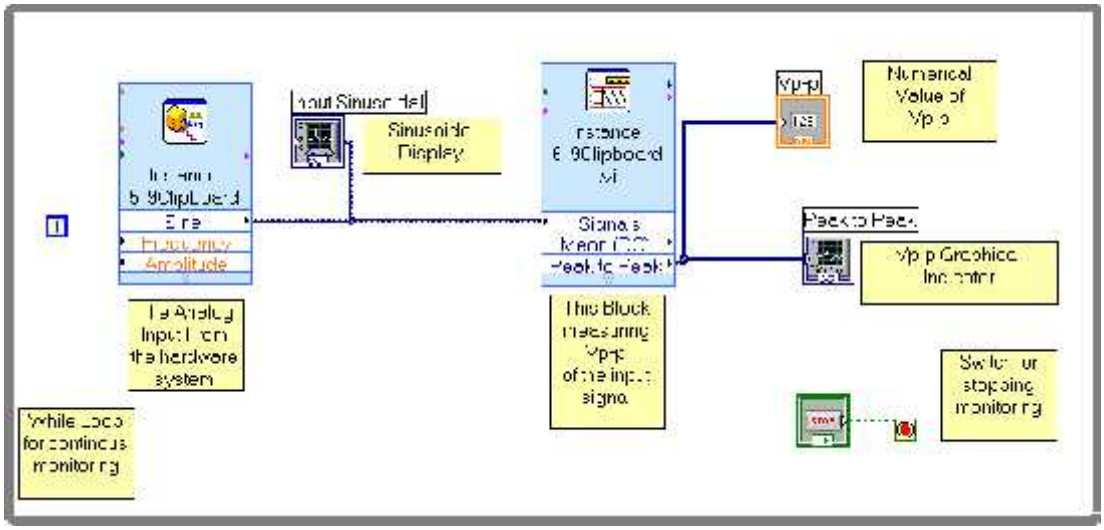

Figure 6.1: Monitoring the Sinusoidal, Peak to peak value of the hardware signal using LabVIEW program

The input data coming in at the DAQ card from hardware devices. Using the Block "DAQ Assistant" from the LabVIEW -after enabling it to read analog input-, the sinusoidal signal will be ready in the PC.

6.4 Flow Chart for input signal from hardware to PC

After interring the signal to the PC, It needs processing to monitor the signal, and monitor its Peak to Peak variation during breathing, and checking the apnea. Figure 6.2 shows the Flow Chart that necessary to do the previous needs. The parameter x is used to specify the time after which the alarm system work when apnea detection –It is normally 10 sec or 20 sec -, and parameter i is used as counter for continuous checking of apnea.

Chapter Seven

Results

7.1 Results

We took a number of samples of volunteer to show how the signal changes during breathings, and we found there is a clear change of peak value of the Band-pass filter signal during breathing.

The signal which was detected contains both the carrier signal (sinusoidal signal) and the impedance change associated with the respiration. The carrier signal was detected clearly, the impedance change associated with the respiration also was detected but of course it was smaller than the carrier signal.

The following figures show the output of each stage of the hardware system:

Figure 7.1 is the output of the transformer which amplifies the oscillator output; we note the clearance and smoothness of the signal.

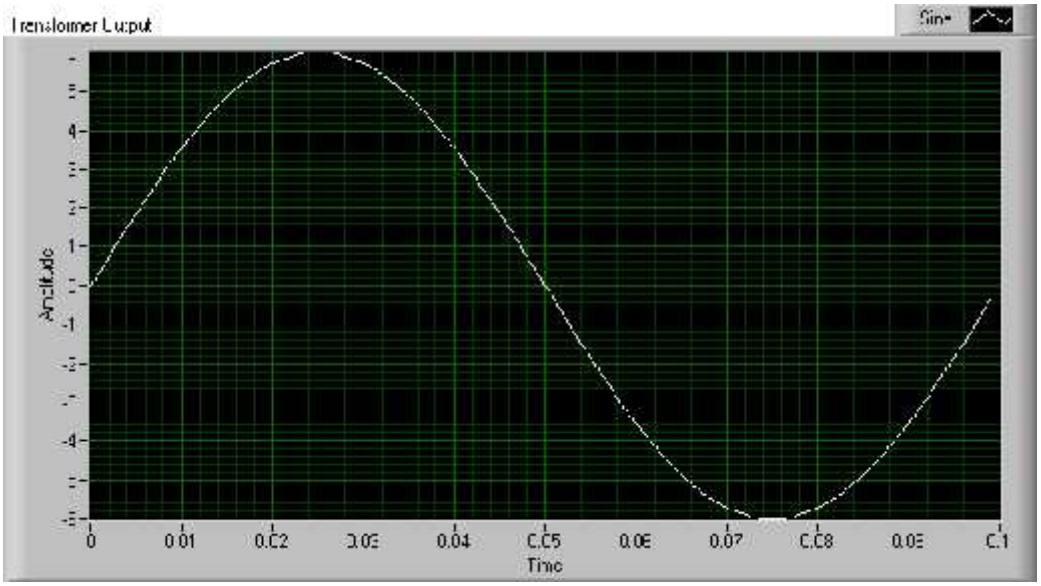

Figure 7.1: Transformer output.

Figure 7.2 is the output of Differential Amplifier which used to amplify the detected signal from the patient chest. We note that this signal has a noise which will be removed in the next stage.

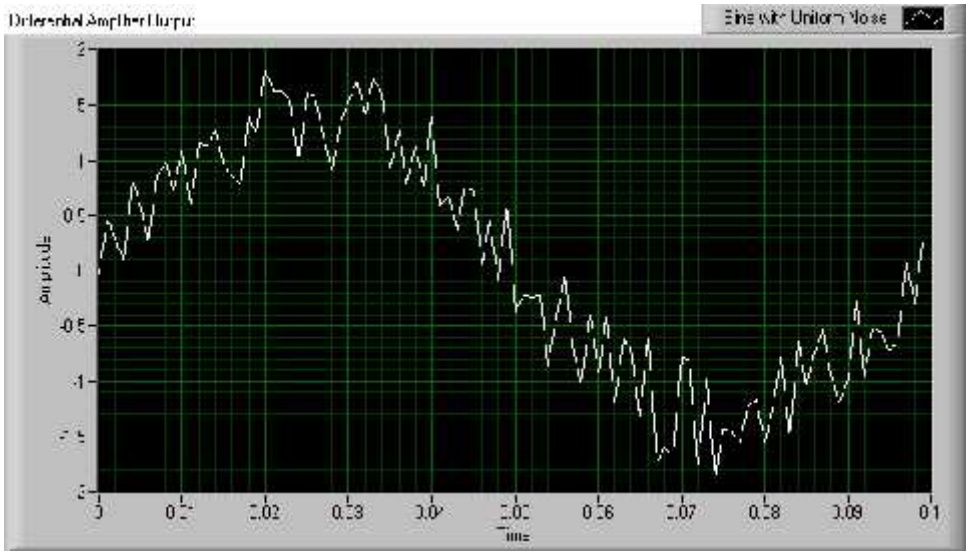

Figure 7.2: Differential Amplifier Output.

Figure 7.3 is the output of Band Pass Filter which used to filter the signal and remove its distortion. We note the clearance and smoothness of the signal.

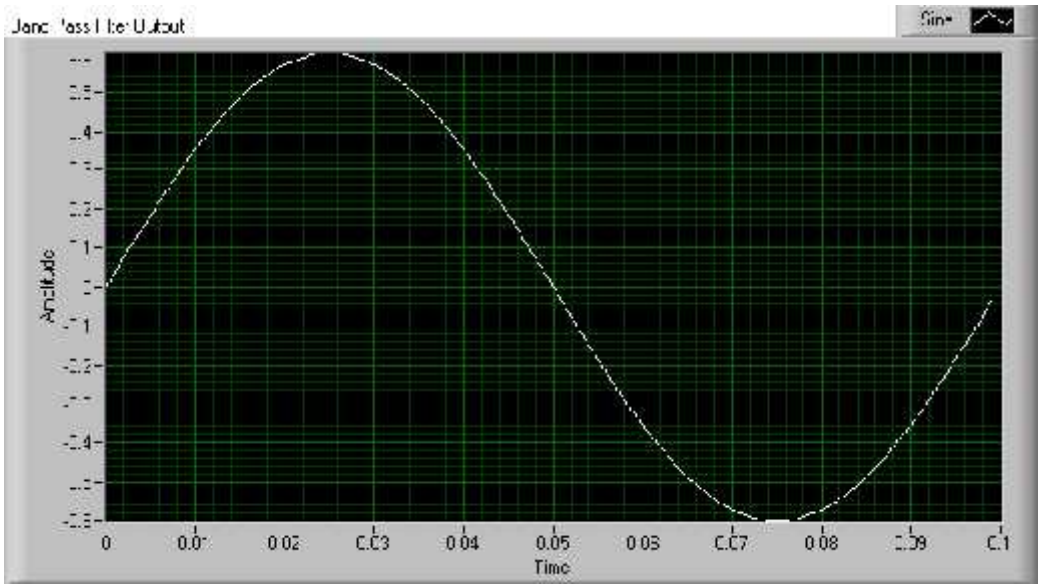

Figure 7.3: Band Pass Filter Output.

7.2 Analysis of Results

As we know the biomedical signals are small signals (measured in mV) that are riding on large common mode voltage, also the biomedical instruments uses special electronic components, and need special conditions such as shielding the instruments, and wires…….etc.

The previous reasons justify that the impedance change associated with the respiration gives small signal in comparison with the carrier signal which was about 60 mV voltage change.

At each stage of the hardware system we measured the value of the output signal and its noise in order to calculate the signal to noise ratio; at the Differential Amplifier stage the signal voltage was about 2.75 Vp-p, the noise voltage was about 0.25 Vp-p. At the Band Pass Filter stage the signal voltage was about 1.2 Vp-p, the noise voltage was about 0.025 Vp-p.
Using the signal to noise ratio Law which given as:

$$SNR = 20\log\frac{signal(r.m.s)}{noise(r.m.s)}$$

We can calculate the SNR for each stage in our system which was:

- The signal to noise ratio of the Differential Amplifier Output about 21 dB.
- The signal to noise ratio of the Band Pass Filter about 33.62 dB.

Chapter Eight
Conclusions and Future Works

8.1 Conclusions

1. We design a respiratory monitor system using impedance Plethysmography technique that can be a good monitoring of respiration.

2. The impedance change associated with the respiration gives small signal because all of the biomedical signals are small signals (about 60 mV).

3. The best position of the electrodes is on each side of the thorax along the midaxillary line.

4. The adhesive Ag-AgCl disposable electrodes produced stable, reproducible signals.

5. The signal to noise ratio of the Differential Amplifier Output about 21 dB.

6. The signal to noise ratio of the Band Pass Filter about 33.62 dB.

7. This system applies high frequency current (about 50 Khz) to Avoid muscle and nerve stimulation.

8. This system can be used for several application such as Holter, and Edema Guard Monitor.

8.2 Future Works

For the student who would like to complete for this project:

1. They can use our system which depending on Impedance Plethysmography for measure another physiological parameter such as cardiac output, and other parameters that depending on the volume changes.

2. Also they can improve the project for diagnostic diseases.

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[15] http://www-ee.eng.buffalo.edu/faculty/paololiu/edtech/roaldi/tutorials/labview.htm

[16] www.datasheetcatalog.com

Appendix A

Circuit Diagram

Appendix B

قاموس المفردات

Appendix C

الجهاز التنفسي

Appendix D

Data Sheet [16]

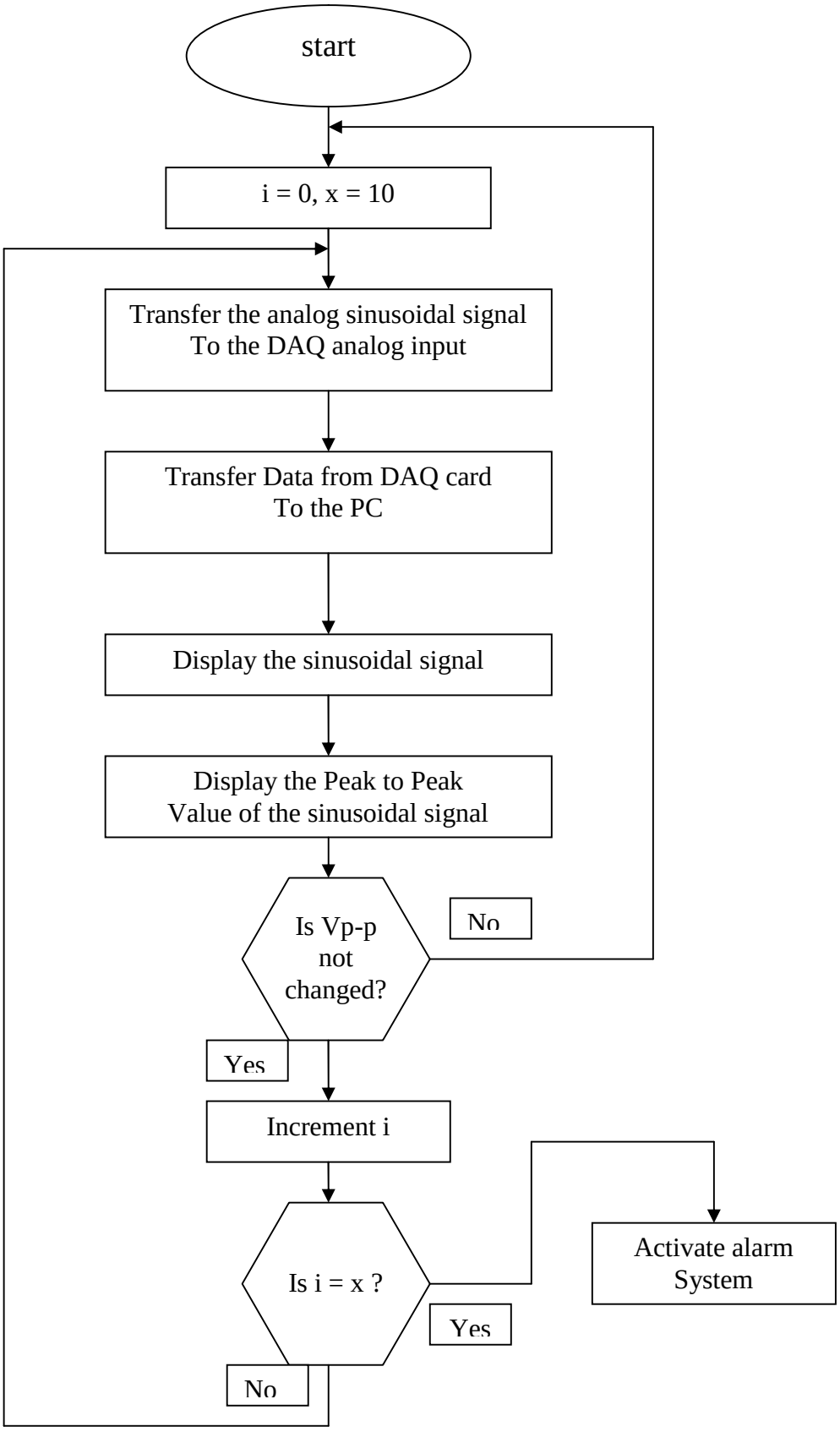
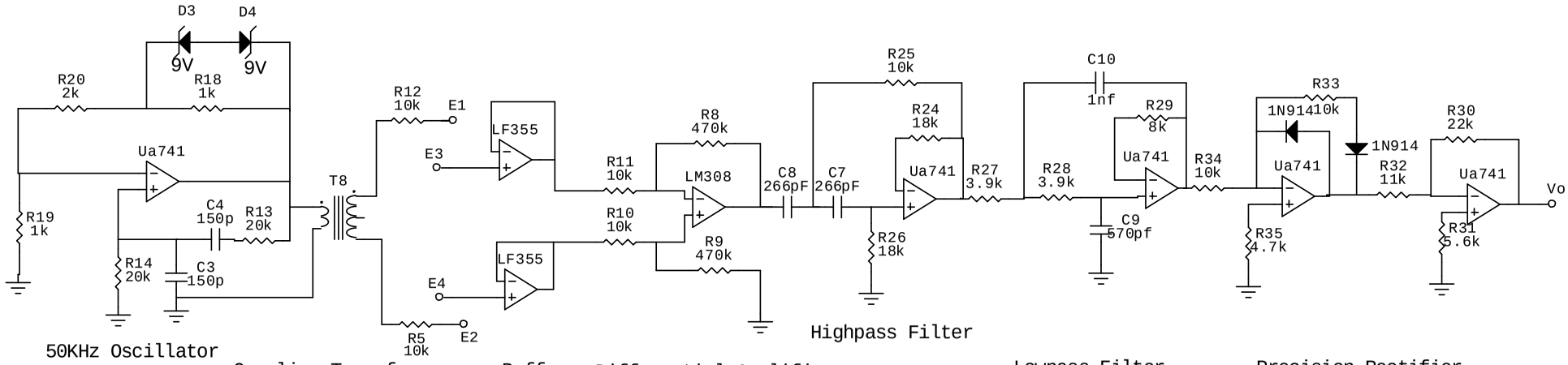
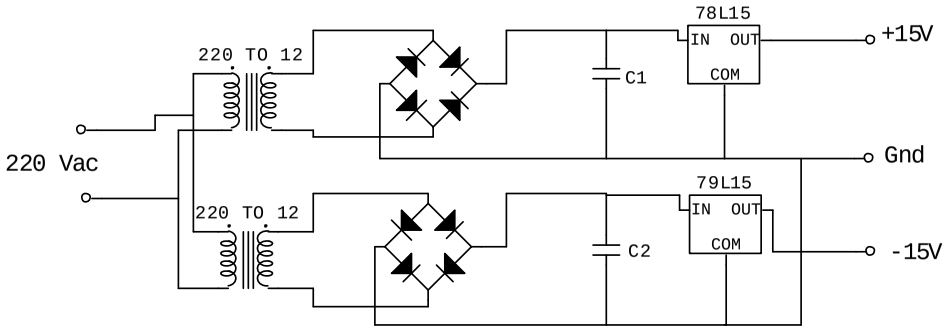
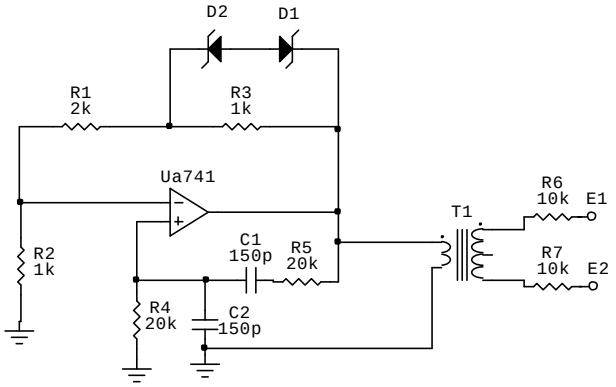


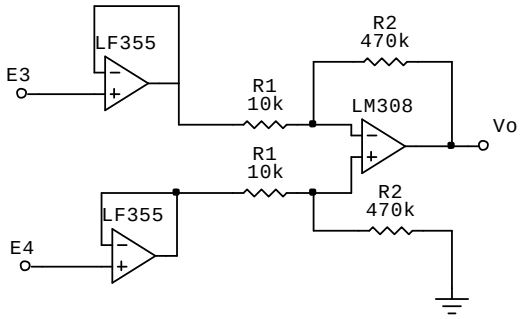
Figure 6.2: Flow Chart for input signal from hardware to PC

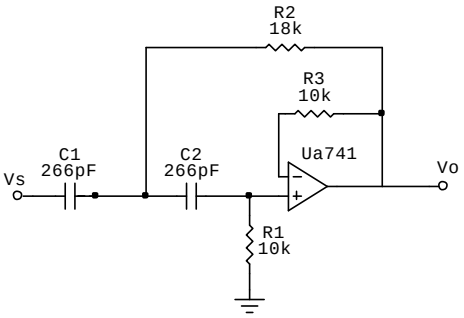


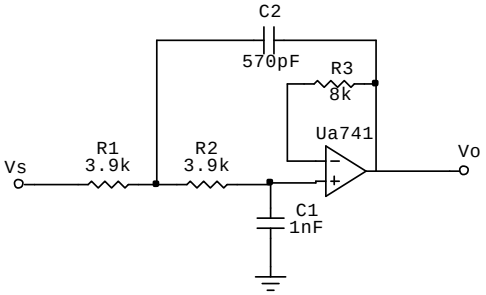


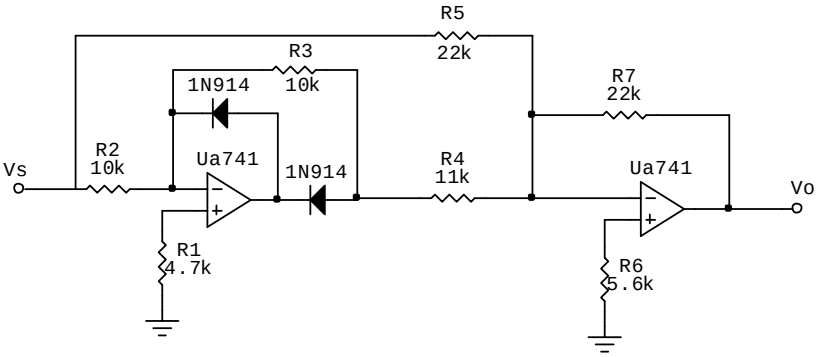
Power Supply


D2
D1
R1
2k
R3
1k
Ua741
R6
10k
E1
T1
R7
10k
E2
R2
1k
C1
150p
R5
20k
R4
20k
C2
150p


LF355
R2
470k
E3
R1
10k
LM308
Vo
R1
10k
R2
470k
LF355
E4


R2
18k
R3
10k
C1
266pF
C2
266pF
Ua741
Vs
Vo
R1
10k


C2
570pF
R3
8k
Ua741
R1
3.9k
R2
3.9k
Vs
Vo
C1
1nF


R5
22k
R3
10k
1N914
R7
22k
R2
10k
Ua741
1N914
R4
11k
Ua741
Vs
Vo
R1
4.7k
R6
5.6k