Palestine Polytechnic University (PPU)

College of Engineering and Technology
Electrical and Computer Engineering Department

Graduation Project

Bioelectric Impedance Measurements

Project Team

Nadia AL-Manasra

Nehal AL –Amleh

Project Supervisor

Eng.Abdullah Arman

Hebron-Palestine

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Abstract

Bioelectric tissue impedance measurement to determine or infer biological information has a long history dating back to before the turn of the century.

BEI measurements are commonly used in, cardiac measurement, body composition, and peripheral blood flow that we will cover it in our project.

Impedance plethysmography is a measurement technique that measures the change in blood volume (venous blood volume as well as the pulsation of the arteries) for a specific body segment. This report will describes briefly the anatomy of the blood vessel in the limb, the biomechanics of blood flow, and the approximation model of the human limb. In order to apply this technique we want to construct a constant current source (2 mA,50KHz) this current will apply to the patient limb by two electrodes ,then an electrical signal will be taken by another tow electrodes as a result of changing in impedance according to the blood movement .A full descriptions for applying this technique in successful way will be considered in this report .

ملخص للمشروع

ان قياس المقاومه الكهربائيه الحيويه للانسجه في جسم الانسان التي تستخدم لتحديد المعلومات الحيويه يعود تاريخها الى بدايات القرن العشرين.

هذه المقاومه الحيويه تستخدم بشكل واسع في القياسات المتعلقه بالقلب, ومكونات الجسم , و مقدار التدفق الدموي في الاطراف , وهو ما سنقوم بتغطيته في مشروعنا هذا.

Impedance Plethysmography التي تعني التغير في الحجم هي طريقة قياس يستخدم لتحديد التغير في حجم الدم في جزء محدد من الجسم.

هذا المشروع سوف يقوم بوصف دقيق للتركيب التشريحي للوعاء الدموي في الأطراف , وآلية تدفق الدم فيها والتصميم التقريبي للوعاء الدموي والانسجه المكونه لأطراف. من أجل تطبيق هذه التقنيه نريد أن نصمم مصدر تيار ثابت بقيمة (2ma,50KHz) هذا التيار سوف يطبق على أحد أطراف المريض بواسطة الكترودين , نتيجة لسريان هذا التيار سوف يحدث تغير في المقاومه في تلك المنطقه ويمكن الكشف عن ذلك عن طريق استخدام الكترودينلآخرين والحصول على اشارة جهد.

سوف يتضمن هذا المشروع وصف تفصيلي للدوائر اللازمه لهذه الطريقه و طريقة تطبيقها والنتائج لها.

List of continents

List of tables

List of Figures

Chapter One

Introduction

1.1 Introduction

In our project we will try to cover one of a non-invasive method for measuring blood flow in human limbs. The idea of our project comes from the fact that the moving blood in the patient limb is considered as a conductor has an impedance comes from blood's component characteristics .When a low current applying to the limb then the impedance of the blood will change as blood flows this change can be result as a voltage signal .

In this technique the electrical impedance of any part of the body is measured by either constant current method or bridge method and variations in the impedance are recorded as a function of time. Since blood is a good conductor of electricity, the amount of blood in a given body segment is reflected inversely in the electrical impedance of the body segment. Pulsatile blood volume increase in the body segment caused by systemic blood circulation therefore, causes proportional decrease in the electrical impedance. Variation in the electrical impedance thus yields adequate information about the blood circulation.

There are many applications for this method like measuring the apnea monitoring, cardiac measurement, body composition, and peripheral blood flow that we will cover it in our project

1.2 Project Objectives

The main objectives of this project are:

1. Applying one of non-invasive technique for blood flow measurement.
2. To get rid off the limitation for measuring blood flow invasively.
3. To reduce the electrical hazard on the patient.
4. Measuring blood flow is an important parameter in human body's circulating system for many indications and study cases.

1.3 What is the importance of the project?

The importance of this project is that a safely, non-invasive, simple but elegant and quick method for blood flow measurement for physicians to determine their decision about the patient state. Plethysmography has been instrumented in studying the role of the autonomic nervous system in regulating limb blood flow in humans and important in studying the vasodilator responses to exercise, reactive hyperemia, body heating, and mental stress. It has also been the technique of choice to study how human blood vessels respond to a variety of exogenously administered vasodilators and vasoconstrictors, especially those that act on various autonomic and adrenergic receptors.

1.4 Literature Reviews

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

1. The first project was prepared by Kathleen Wilkie ,98181130,April 4 2004.under The title "Human Blood Flow Measurement And Modeling" . It talks about the circulatory system and the modeling form for the measurement [1].

2. The second project is prepared by Michel J.Joyner , Niki M.Dietz , and John T.Shepherd. Departments of Physiology and Biophysics and Anesthesiology, Mayo Clinic and Foundation, Rochester, MN 55905 .under the title "From Belfast to Mayo and beyond: the use and future of plethysmography to study blood flow in human limbs which talks about the developments of plethysmography techniques for measuring blood flow and the cases that can be studied using those techniques [2]

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.

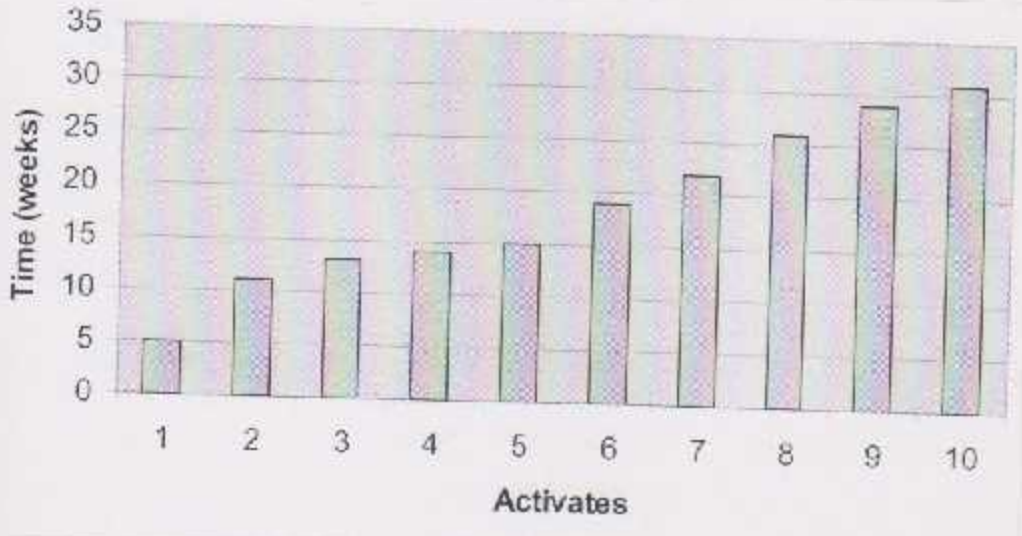

Figure 1.1: Time plan

Table 1.1: Time scheduling

Time (Weeks)	Activates
5	Study Impedance plethysmography technique
11	Study cardiovascular system
13	Study tissue characteristics
14	Litrechare reviews
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
31	Testing System performance

1.6 Economical Study

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

Table 1.2: Economical study

Component	Coast (SHEQALIM)
transformers	50
Electrode leads	150
Zener Diodes	10
UA714	20
Resistors	20
Capacitors	20
Board	30
Total Coast	300

1.7 Project Contents

The report is divided into four chapters, as follows:

Chapter one: Introduction

Chapter two: Physiology and Mechanism of Cardiovascular System

Chapter three: Impedance Plethysmography and Tissue Impedance

Chapter four: Applications of Impedance Plethysmography

Chapter five: Design Concept

Chapter six: Conclusions

Chapter seven: Results

Chapter Two

Physiology and Mechanism of Cardiovascular System

2.1 Introduction

In order to achieve our goals in this project we must first understand so many physiological concepts include blood flow mechanism, blood flow regulation, circulatory system, structure of blood vessels, and all the factors that affecting blood flow measurements.

2.2 The Circulatory System

The circulatory system is divided into two main components:
The cardiovascular system and the lymphatic system. Here we will focus on the cardiovascular system which consist of blood, blood vessels, and heart. Blood acts as a transport mechanism to the cells for nutrients and wastes. Blood vessels provide a tubular network to channel the blood to every possible region of the body and the heart creates the pressure required to push blood through the vessels.

2.2.1 The Composition of the Blood

Blood is composed of fluid plasma, formed elements, and other elements either being carried to or away from cells. Blood plasma is a liquid that serves as the intracellular environment for the cells in the body. Total volume of plasma is important in the regulation of blood pressure. The sodium ion is the major solute in plasma, and it's concentration is what determines the amount of the plasma water and thus blood volume.

Total blood volume in an average adult is about 5 liters , or 8% of the total body weight. Formed elements constitute about 45 % of the total blood volume and blood plasma makes up the remaining 55 %. The percentage of formed elements closely approximates the percentage of RBCs per given volume of the blood. This is an important measure in heath care as it is an indicator of the oxygen – Carrying capacity of the blood.

The formed elements of the blood are:

Red Blood Cell: RBC

- The main purpose is the transport of oxygen to the tissue and pickup CO_2.
- Don't have a cell nucleus.
- It is concaved disc-shaped cell.
- The diameter of a typical human erythrocyte is 6-8 μm.
- It's number 4.5 – 5.5 million cells/ mm. cubic.
- Each red blood cell contains four iron atoms in structure know as the hemoglobin Hgb.

White Blood Cell: WBC

- Act as immune cells and fight infection.
- Normally between 4Gega & 11Gega WBC in a liter of healthy adult blood.
- Have nucleus.
- It's number (6 – 10)*1000 cells/mm.cubic.
- The circulating life is 13 – 20 days.
- 10μm in diameter.

Platelets are:

- A nuclear and discoid.
- Size 1.5 – 3.0 μm.
- The circulating life is 9 – 10 days.
- Produced in the bone marrow.
- It's number (200 – 800)*1000 cells /mm.cubic.
- A normal platelet count in healthy person is between (150 - 400)*Gega /L of blood.
- Responsible for coagulation and clotting.

2.2.2 Blood Vessels

One of our needed in this project is to the tubes through which the blood passes. Their structure enables the exchange of blood plasma and dissolved molecules between the blood and surrounding tissues. Blood travels away from the heart passing through a series of vessels progressively smaller in diameter; arteries to arterioles to capillaries. Blood returns to the heart through a series of vessels progressively larger in diameter; capillaries to venules to veins. The walls of arteries and veins consist of three layers.

The outermost layer is the tunica external it is composed of loose connective tissue. The middle layer is the tunica media it is composed of smooth muscle. The innermost layer is the tunica intimae it is composed of the endothelium and connective tissue. The endothelium lines all inner walls of vessels and capillaries consist only of the endothelium. Arteries contain more muscle than comparably sized veins. Large arteries stretch when the pressure of the blood rises during systole and recoil during diastole the elastic recoil of the walls helps to produce a smoother flow of blood in the smaller arteries and arterioles. However the result is a cardiac cycle dependent artery diameter. Smaller arteries and arterioles are less elastic than larger arteries and contain a proportionally thicker layer of smooth muscle. Thus they maintain a relatively constant diameter. Capillaries are the simplest structured vessel. They are composed of single cell layer of endothelium and are about 8 mm in length. They permeate the entire body in a fine mesh to provide the surface area for blood and interstitial fluid transfer. Capillaries only contain about 250 ml of blood at given time. The amount of blood in a capillary bed is regulated by the precapillar sphincter muscles and by the resistance to blood flow provided by the small arteries and arterioles. Blood is transported back to the heat by venules which empty into progressively.

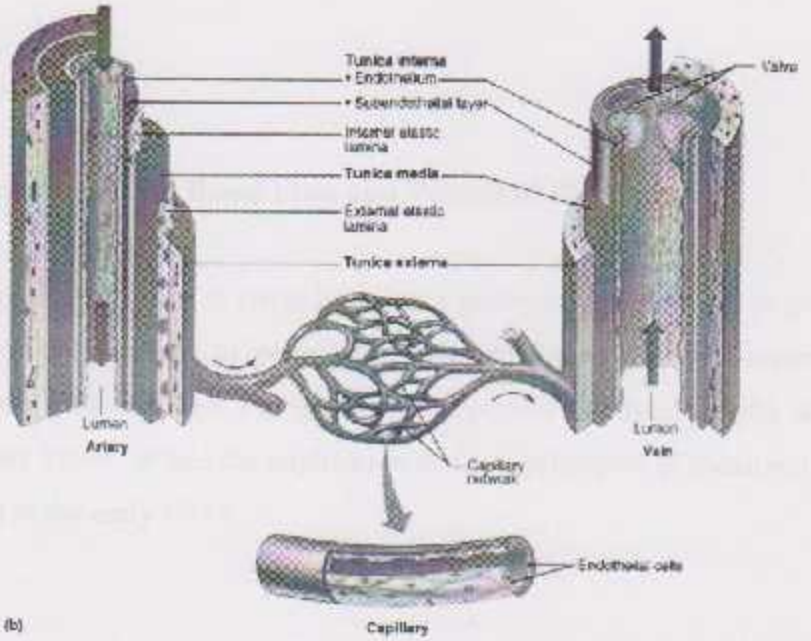

Figure 2.1: Internal construction of the blood vessels (artery, vein, and capillary)

2.3 Regulation of Blood Flow

Blood flow to an organ is controlled by the constriction and dilation of vessel walls. The changes in vessel diameter are regulated by sympathetic interaction and by local conditions within the blood vessel and organ. Sympathetic nerve stimulation causes vasoconstriction in the viscera and skin, and vasodilatation in the skeletal muscles. Myogenic regulation, in the cerebral arteries, causes the dilation of vessels in response to a decrease in blood pressure, and vice versa. Metabolic regulation, in the skeletal and cardiac muscle vessels, promotes vasodilatation based on local conditions such as oxygen concentrations, carbon dioxide concentrations, tissue pH, and the release of adenosine. The increase in blood flow in skeletal muscles and the heart as a result of increased metabolism is called active hyperemia.

2.4 Measurement of Blood Flow and Volume of Blood

Because we want to cover impedance plethysmograph in our project. We will talk about the development of plethysmograph techniques as a non-invasive method for blood flow measurement. The general principles of plethysmography were appreciated by the late 1800s. While the application of these principles to measure limb blood flow occurred in the early 1900s.

Water-filled plethysmograph

With the use of this technique, the forearm was placed in a vessel, and water-tight seals were made at either end. The rate of blood flow was estimated based on the water displaced from the plethysmograph. This technique was in wide use throughout the 1930s and 1940s and required some interesting adaptations to make it work. First, sealing the forearm within the plethysmograph was always challenging, and, second, it was necessary to keep the water temperature in the plethysmograph at 34-35°C. This was accomplished by applying a Bunsen burner to the metal jacket while stirring the water with a bulb syringe attached to the plethysmograph.

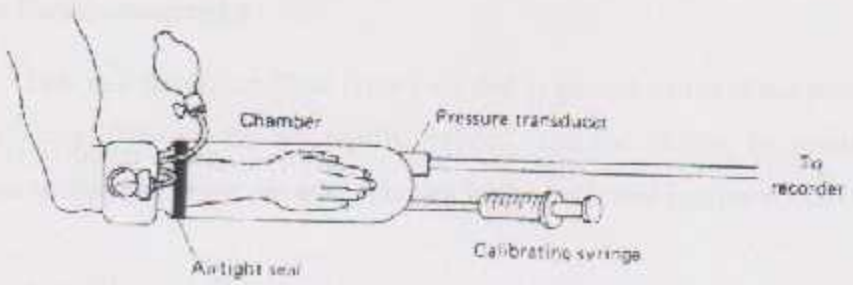

Figure 2.2: Water-filled plethysmograph [7]

Mercury-in-Silastic strain gauges

Which are still commonly used. A thin silastic tube is filled with mercury, and a small electric current is passed through the mercury. When the veins are occluded and the limb expands, the silastic is stretched, which reduces the diameter of the tubing and increases the electrical resistance. Properly calibrated, the change in electrical resistance has a linear relationship with change in forearm circumference and hence provides an estimate of volume and flow.

Because the early investigators did not have access to laboratory-based computers and advanced calculators, the initial formula used to estimate changes in forearm volume from changes in strain-gauge length used simple arithmetic and assumed the forearm was a cylinder. However, these simple assumptions have proven to be remarkably valid over a wide range of flows.

Dohn Plethysmography

This is a small, air-filled latex cuff that is placed on the distal portion of the limb under study. These cuffs are lightly inflated, and the change in volume seen during venous occlusion causes a rise in pressure in the cuffs that is proportional to the flow.

Photoplethysmography

This device operates on the principle that volume changes in the limb or digit result in changes in the optical density through and just beneath the skin over a vascular region. When the light source illuminates a small area of the fingertip or other region. Light scattered and transmitted through the capillaries of the region is picked up by the photocell. As the capillaries fill with blood, the blood density increases, thereby reducing the amount of the light reaching the photocell .The result causes resistance changes in the Photocell that can be measured on a Wheatstone bridge and recorded.

Impedance plethysmography

Impedance plethysmography is a measurement technique that measures the change in blood volume (venous blood volume as well as the pulsation of the arteries) for a specific body segment. As the blood volume changes, the electrical impedance (resistance) also changes. This electrical impedance is measured by passing a small amount of alternating current (AC) through the body segment. This technique is noninvasive(no surgery is needed) because the amount of AC current is so small that the patient does not feel any sensation from the probe.

Figure 2.3: How we can apply Impedance plethysmography [10]

Chapter Three

Impedance Plethysmography and Tissue Impedance.

3.1 Introduction

Impedance Plethysmography gives an indirect assessment of central and peripheral blood flow non-invasively. Since blood is a good conductor of electricity, any change in blood volume in any part of the body is reflected in its electrical impedance. Thus a record of gross electrical impedance of the body segment, change in the impedance as a function of time and rate of change of impedance gives an indirect estimate of the central as well as peripheral blood flow. Change in the blood volume V in a body segment of volume V and electrical impedance Z is related to the change in the impedance Z by the Nyboer's equation This method has been observed to be 96% sensitive and 98% specific for the diagnosis of arterial occlusive disease and greater than 85% sensitive for the diagnosis of deep vein therombosis and valvular diseases of the heart.

3.2 Definition of Impedance Plethysmography

Impedance plethysmography is a measurement technique that measures the change in blood volume (venous blood volume as well as the pulsation of the arteries) for a specific body segment. As the blood volume changes, the electrical impedance (resistance) also changes. This electrical impedance is measured by passing a small

amount of alternating current (AC) through the body segment. This technique is noninvasive because the amount of AC current is so small that the patient does not feel any sensation from the probe.

3.3 Tissue Impedance

In the body, highly conductive lean tissues contain large amounts of water and conducting electrolytes, and represent a low resistance electrical pathway. Fat and bone, on the other hand, are poor conductors or a high resistance electrical pathway with low amounts of fluid and conducting electrolytes. The physical quantity measured in impedance plethysmography (and imaged in impedance tomography) is tissue impedance. It can be seen that the resistivity of body organs varies about 100-fold from about 1.6 Wm in blood to about 170 ? in bone. Within the soft tissues the variability is about 10-fold, with about 20 ? in the lung and in fat. The common value of the skin impedance is up to 500 ? .

The equivalent electrical components of the tissue (limb) is consist of both resistor and capacitor as shown in figure 3.1 .

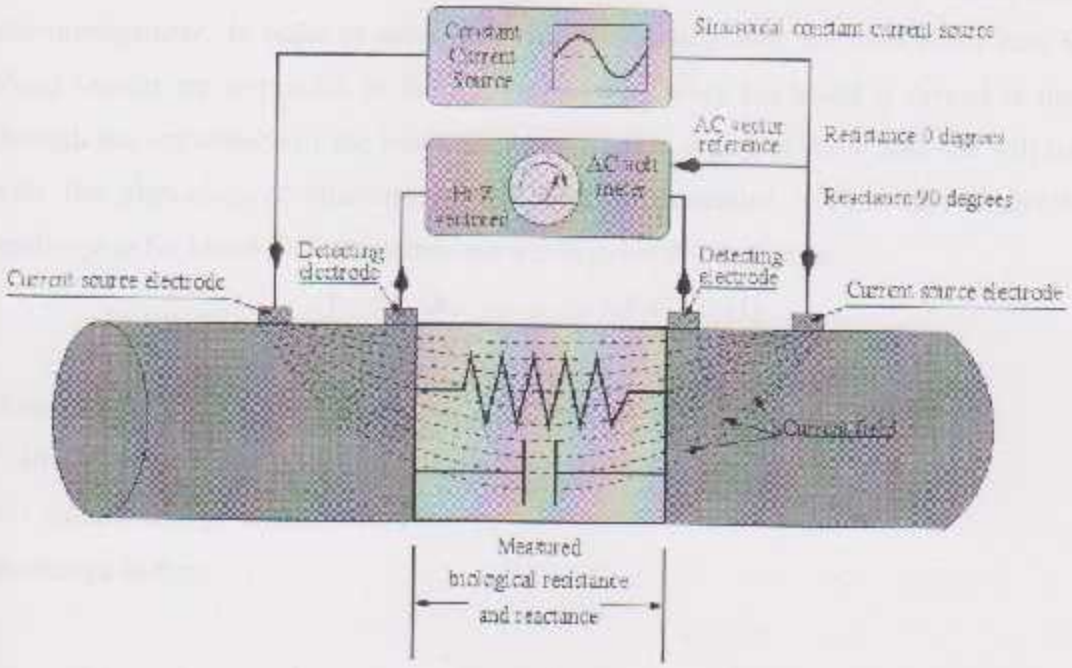

Figure 3.1: Equivalent electrical components of the limb [9]

3.4 Limb modeling

Studies of blood flow in vessels provide a greater understanding of human health and management .In order to use impedance plethysmography we must know how the blood vessels are responded to the applying current when the blood is flowed in them through the occurrence of the blood circulation. Also we must show how we will deal with the physiological structure of the limb to determine a clear and acceptable relationship for blood flow measurement which generally known as:

$$F = dV / dt \qquad 3.4.(1) \quad [1]$$

Where;

F: Blood Flow

dV: volume change of the blood

dt: change in time

The mathematical equations for subject segment were derived assuming a homogeneous volume conductor with uniform cross sectional area and constant distance between potential sensing electrodes. Actually this far from reality in physiological term, because the human limbs has a complicated structure consisting of bone, muscle, fat and blood skin. Also the constant current of (0.5 to 4 mA RMS and 50 to 100 KHz) flows almost through ought the tissue of the muscles and blood because of lower resistivity.

In a very simple model, the impedance of the limb can be considered to be divided into two parts: the impedance of both tissue and fluids, as illustrated in Figure (3.2).

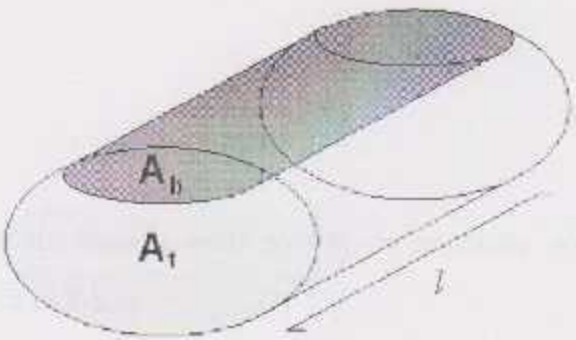

Figure 3.2: Simplified model of the impedance of the limb [11]

To relate blood volume changes to impedance changes, we use the simplified model of the limb, described in Figure (3.2). We designate the cross sections of blood and tissue and their longitudinal impedances by A_b, A_t, Z_b, and Z_t, respectively. The total longitudinal impedance of the model is

$$Z = \frac{Z_b Z_t}{Z_b + Z_t} \qquad 3.4(2)[11]$$

Where;

Z: Is the longtidual impedance of the model

Z_b: is the impedance of the blood volume

Z_t: is the impedance of the tissue volume

The relationship between the impedance change of the limb and the impedance change of the blood volume is found by differentiating previous equation with respect to Z_b:

$$dZ = \frac{Z^2}{Z_b^2} dZ_b \qquad 3.4(3) \quad [11]$$

The impedance of the blood volume with blood resistivity ρ_b based on the cylindrical geometry of Figure (3.2), is:

$$Z_b = \frac{\rho_b l^2}{A_b} \qquad 3.4(4) \quad [11]$$

Where;

ρ_b = blood resistivity

A_b = cross-section of the blood area

l = length of the limb model

The relationship between changes in blood volume v_b and the blood volume impedance is found by solving for the blood volume in Equation 3.4(3) and differentiating:

$$dv_b = d(lA_b) = -\frac{\rho_b l^2}{Z_b^2} dZ_b \qquad 3.4(5) \quad [11]$$

where v_b = blood volume

We finally derive the dependence of the change in blood volume on the change in thoracic impedance by solving for dZ_t in Equation 3.4(2) and substituting it into Equation 3.4 (4):

$$dv_b = -\frac{\rho_b l^2}{Z^2} dZ \qquad 3.4(6) \quad [11]$$

Determining the Stroke Volume

To determining stroke volume from The value of ΔZ is easy to determine with the help of the first derivative. According to the definition of the derivative:

$$\frac{\Delta Z}{\Delta t} = f'(Z) \qquad 3.4(7) \quad [11]$$

Assuming that Δt equals the ejection time t_e, ΔZ can be determined from equation

$$\Delta Z = f'(Z) \cdot t_e \qquad 3.4(8) \quad [11]$$

With the above assumptions, the impedance change ΔZ can be determined by multiplying the ejection time by the minimum value of the first derivative of the impedance curve.

Finally, the formula for determining the stroke volume is obtained by substituting Equation3.4(7) into Equation3.4(5), which gives:

$$SV = \rho_b \frac{l^2}{Z^2} \left|\frac{dZ}{dt}\right|_{min} * t_e \qquad 3.4(9) \quad [11]$$

Where;

SV = stroke volume [ml]

ρ_b = resistivity of the blood [Ω ·cm]

l = mean distance between the inner electrodes [cm]

Z = mean impedance of the thorax

$\left|\frac{dZ}{dt}\right|_{min}$ = absolute value of the maximum deviation of the first derivative signal during systole

t_e = ejection time [s]

Figure 3.3 shows the relation ship between the changes in impedance due to change in time, which we proved in equation3.4 (6) and3.4 (7)

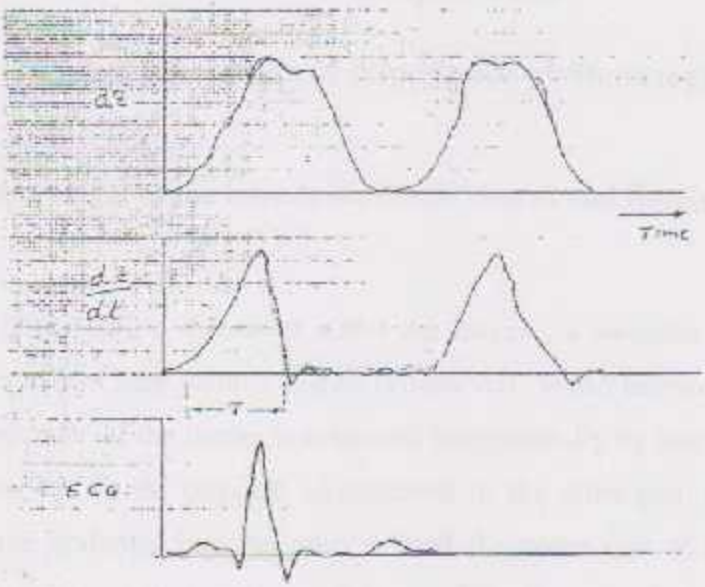

Figure 3.3: Relation ship between changes in impedance due to change in time.

Chapter Four

Applications of impedance plythesmograrphy

4.1 Measurement of the Impedance of the Thorax and Respiratory Monitoring

If the BEI is measured across the thorax , a variation of approximately 1to 2 ohms per liter of lung volume change is observed , which increases with inspiration . The impedance of the thorax is measured longitudinally by four band electrodes, shown in Figure 4.1. In the physical arrangement of the outer pair, one electrode is placed around the abdomen and the other around the upper part of the neck. For the inner electrode pair, one electrode is placed around the thorax at the level of the joint between the *xiphoid* and the *sternum*, called the *xiphisternal joint*, and the other around the lower part of the neck. In recent studies of impedance cardiography, the band electrodes are often replaced with normal ECG-electrodes.

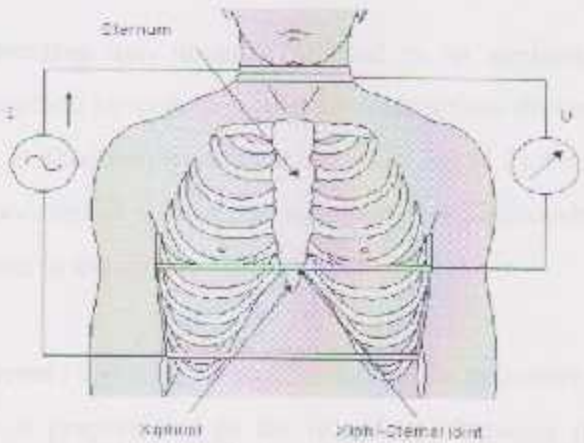

Fig. 4.1: Placement of the band electrodes in the measurement of the thorax impedance. [11]

4.2 Apnea Detection

The determination of apnea or weather respiration has stopped in infants is one of the most widely used applications of BEI. For convenience and due to the lack of space on the thoraces of infants, only two electrodes are used. These are placed at the mid thoracic level along the midaxillary line and are also used to obtain the ECG. No effort is usually made to quantitate the volume change.

Filtering is used to reduce the movements artifacts and automatic gains controls and adaptive threshold detection is used in the breath detection circuits. Due to movements artifacts, the normal breath detection rate in infants is not highly reliable. When respiration stops body movement ceases which eliminates the movements' artifacts and then apnea can be detected.

4.3 Uterine Contraction

Another interesting non invasive method as an application on the impedance plethysmography method is recording uterine contractions during labor in the pregnant human female.The method employed is sketched in fig. (4.2). Four silver electrodes (10-cent coins) were mounted in a band that maintained the electrodes against the abdomen in the position shown in the figure.

A low intensity current (100 KHz) was admitted by the two outer electrodes (I1, I2), and the voltage which is proportional to the impedance between the potential-measuring electrodes (E1, E2), was continuously recorded after amplification and demodulation.

The record of the impedance change between the two potential-measuring electrodes was called an impedance histogram (IHG). A typical example of uterine contractions from pregnant human female appear in figure(4.2), along with the electrohystogram (EHG) , which is a recording of the slow changes in potential detected by electrodes on the abdomen.

On the basis of clinical observation they suggest that the recorded impedance change were related to mechanical displacement of the uterus during contraction.

Impedance hystography would appear to be safe practical method for recording the frequency of uterine contractions with properly placed electrodes, but little use has been made of this technique.

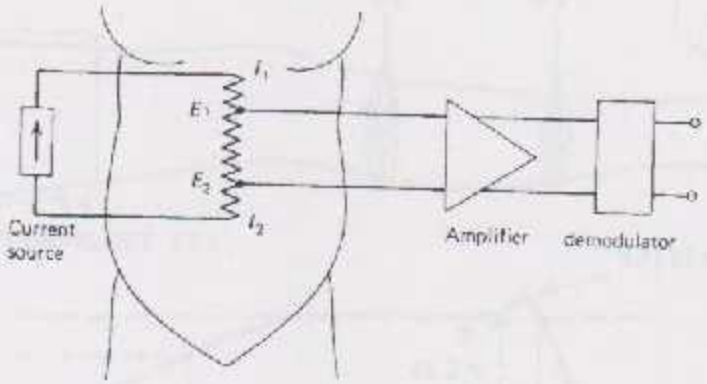

Figure 4.2: Electrodes placement in determining uterine contraction [3]

4.4 Peripheral blood flow

BEI measurements are made on limbs to determine arterial blood flow into the limb or for the detection of venous thrombosis. In both applications, an occluding cuff is inflated above venous pressure prevent out flow for a short period of time.

Figure (4.3) shows the typical electrode arrangement on the leg and the position of occluding cuff. The cuff is rapidly inflated to 40 to 50 mmHg, which prevents venous outflow without significantly changing arterial inflow. The arterial inflow causes increase in the volume of the limb. The slope of the initial impedance change as determined by the first or four beats is used to measure the arterial flow rate.

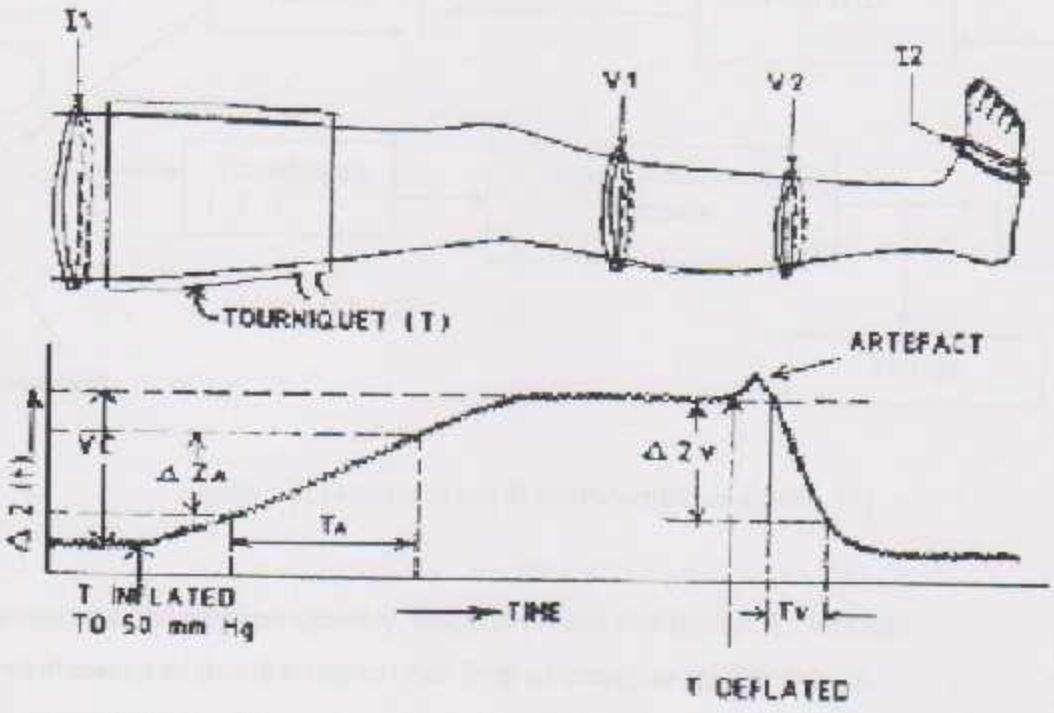

Figure 4.3: Measurement of arterial inflow and venous outflow. [5]

Chapter Five

Design concepts

5.1 Biosignal processing

Before we start discussing the main block diagram, we want to discuss the general medical instrumentation system

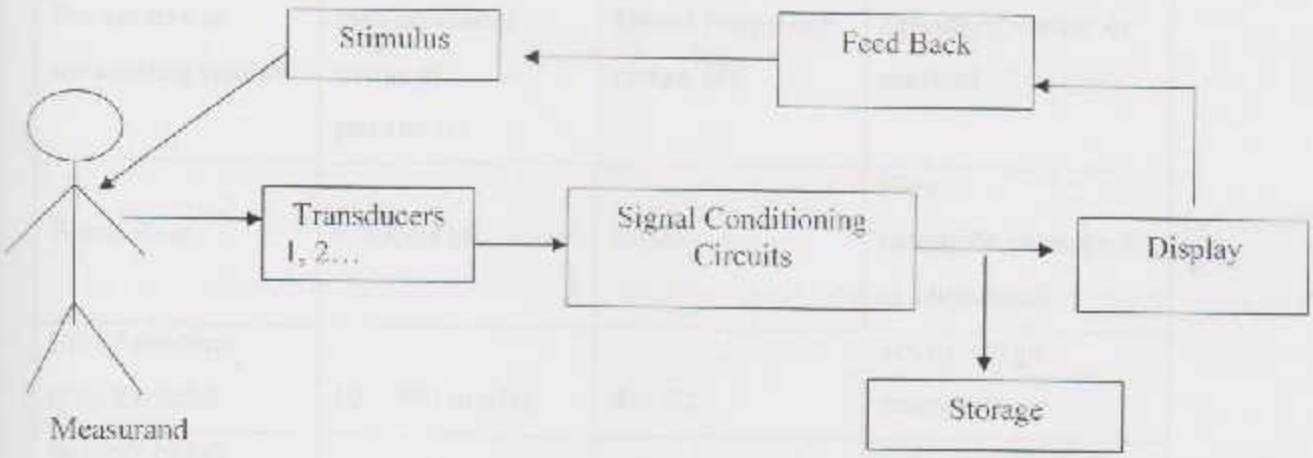

Figure 5.1: General medical instrumentation system. [4]

Measurand: the physical quantity, property patient that the system measure.

Transducer: a device that convert one form of energy to another form.

Signal conditioning Circuit: may include amplifier, filters, and matching circuits.

Display: must be displayed in a form that the physician can understand (include numerical, graphical, continuous form, discrete form).

Auxiliary element: include feed back, storage for communication goals and stimulus.

5.2 Medical measurement constrains

1- Frequency ranges of biomedical signal are too small as shown in table 5.1

Table 5.1: Medical and physiological parameters.

Parameter or measuring equine	Principal measurement range of parameter	Signal frequency range, Hz	Standard sensor or method
Blood flow	1-300ml/sec	dc-20	Flow meter(electromagnetic or ultrasound)
Blood pressure direct(arterial	10 – 400 mmHg	dc - 50	Strain – gage manometer
Indirect blood pressure	25 – 400 mm Hg	dc - 60	Cuff , auscultation
Cardiac output	4 – 25 liter / min	dc - 20	Dye dilution , flow meter
Plethysmography (volume change)	Varies with organ Measured	dc - 30	Displacement chamber or impedance
Respiration rate	2 – 50 breaths / min	0.1 - 10	Strain gage on chest , impedance

2. Low voltage: most of the biological signals having low amplitude (μV – mV).
3. Inaccessibility of biomedical parameter cannot be measured.
4. Sensor size: may affect the measurement
5. Variations of the of a parameter with time.
6. Parameter may affect other parameter
7. External energy may damage the tissue
8. Safety problem.
9. Lack of knowledge about human body.

5.3 How System Work

In figure 5.2 which show the general block diagram of the measurement system. It consists from an oscillator, constant current source, electrodes, Instrumentation amplifier, optocouplers,amplitude detection (active demodulator) ,and display for output signal .

Measuring the impedance changes (and with them the blood volume changes) requires 4 electrodes as shown in figure5.2. The two middle electrodes detect a voltage, and their placement defines the measurement segment. That means that the blood volume changes between these two electrodes are measured. The outer electrodes are used to emit the small imperceptible current required to measure the impedance. By using a RF oscillator to obtain wanted frequency of nearly 50 k Hz to construct a constant current source that Supply the system with a small amount of ac current (say nearly 2 mA) with high frequency to certain that there is no stimulation for skeletal muscle of the tested segment of the limb . Due to the change in the limb volume because of the blood flow

which make a change in the impedance of that limb, this change can be detected as a developing voltage by using another electrodes.Because the output signal is very small in it's value, then by using an instrumentation amplifier to amplificate this signal and reduce the noise by using a proper filter , getting a suitable output signal .

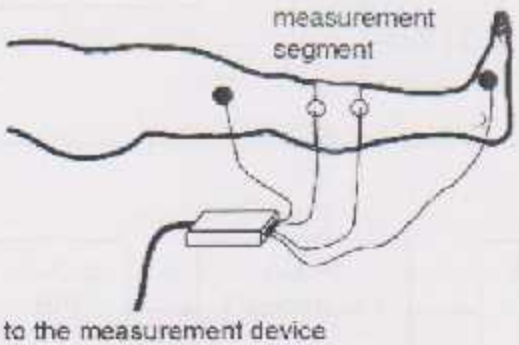

Figure 5.2: Applied Electrodes in Limb Blood Flow. [10]

The general block diagram of impedance pletysmography for measuring blood flow is shown in figure 5.3.

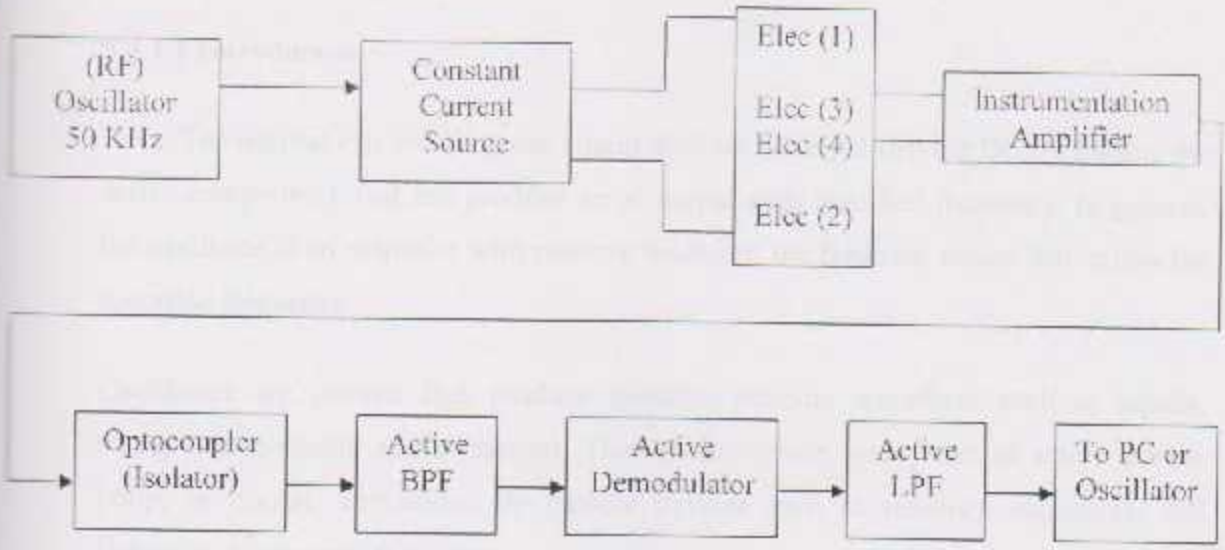

Figure 5.3: The general block diagram for impedance plethysmography technique for measuring blood flow in human limbs .

5.4 Detailed Description

5.4.1 Oscillator

5.4.1.1 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.

Oscillators are circuits that produce specific, periodic waveform such as square, triangular, sawtooth, and sinusoidal. They generally use some form of active device, lamp, or crystal, surrounded by passive devices such as resistors, capacitors, and inductors, to generate the output.

There are two main classes of oscillators: Relaxation and Sinusoidal.
Relaxation oscillators generate the triangular, sawtooth and other non sinusoidal waveforms. Sinusoidal oscillators consist of amplifier with external components used to generate oscillation, or crystals that internally generate the oscillation. We focus here on sine wave oscillator, created using operational amplifier op Amps.

There are many types of sine wave oscillator circuits and variants in application; the choice depends on the frequency and the desired monotonicity of the output waveform. The focus of our project is on the type called wein bridge oscillator

5.4.1.2 Wein-Bridge Oscillator

The Wein-Bridge is one of the simplest and best known oscillators and is used extensively in circuits of audio application. Also we chose it our project because it satisfies bark house conditions:

1. Closed loop gain must be equal one.

$A_{cl} = 1$

$|A_{cl}, \beta| = 1$

2. Phase angle of the closed loop is zero.

The figure bellow shows the basic wein bridge circuit configuration

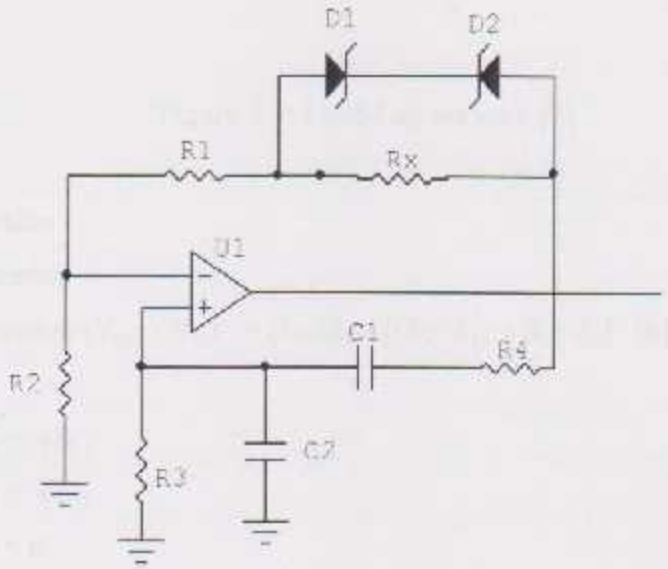

Figure 5.4: Wein-bridge oscillator [6]

Proof

A fundamental part of the wien bridge oscillator is the lead-lag network like that show in figure (5.5). R_4 and C_2 together form the lag portion of the network;R_3 and C_1 form the lead portion. The operation of this circuit is as follows. At lower frequencies, the lead network detonates due to the high reactance of C_1. As the frequencies increase Xc_1 decreases, thus a lowing the output voltage to increase. At some specified frequency, the respond of the lag network takes over: the decreasing value of Xc_2 causes the output voltage to decrease.

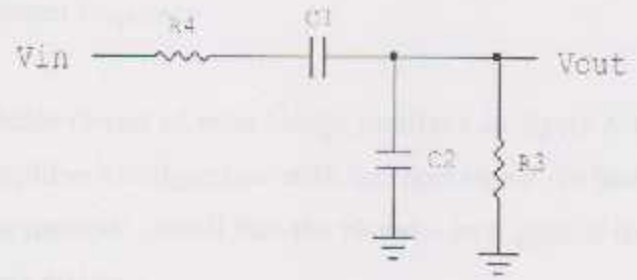

Figure 5.5: Lead-Lag network [6]

R_4 - C_2: lag portion

R_3 – C_1: lead portion

The transfer function $(V_{out} / V_{in}) = (R_2//Z_1)/ [(R_2//Z_1) + R_1+Z_2]$ [6]

Where;

$Z_1 = 1 / 2\pi f c_2 = -jX_{c2}$

$Z_2 = 1 / 2\pi f c_1 = -jX_{c1}$

Chose $R_3 = R_4 = R$

$C_1 = C_2 = C$

$$\Rightarrow (V_{out} / V_{in}) = \frac{R\,(-jx) / (R-jx)}{(R-jx) + [R\,(jx) / R-jx]} \qquad [6]$$

By simplifying it we have:

$(V_{out} / V_{in}) = RX / 3RX + j (R^2 - X^2)$ [6]

For 0° phase shift.

$(V_{out} / V_{in}) = RX/3RX = 1/3 = \beta$ [6]

$R^2-X^2 = 0 \Rightarrow R = X = 1/2\pi f_r C$

Where:

β is the loop gain .

f_r is the resonant frequency.

The basic circuit of wien bridge oscillator in figure 5.4 can be viewed as a non inverting amplifier Configuration with the input signal fed back from the out put through the lead- lag network . recall that the closed - loop gain of the amplifier is determined by the voltage divider :

$A_{cl} = (1+ R_f / R_{in}) = (1+ R_1 /R_2)$ [6]

$|A_{cl}. \beta| = 1$

ACL. (1/3) = 1 $\Rightarrow$ the closed loop gain must be equal to 3.

$3=1+R_1/R_2 \Rightarrow R_1=2R_2$.

Start up condition

Initially the closed loop gain of the amplifier must be than 1 (A_{CL}> 3) until the output signal builds up to a desired level . the gain must then decrease to 1 so that the output signal stays at the desired level . This is illustrated in figures (5.6), (5.7), and (5.8) respectively.

If $\beta = 3$, oscillations occur

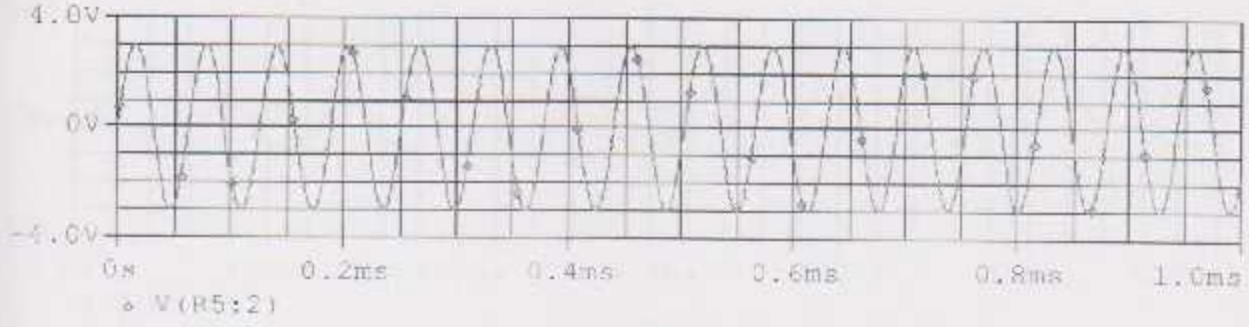

Figure 5.6: Oscillation with $\beta = 3$ [12]

If $\beta < 3$, oscillations attenuate

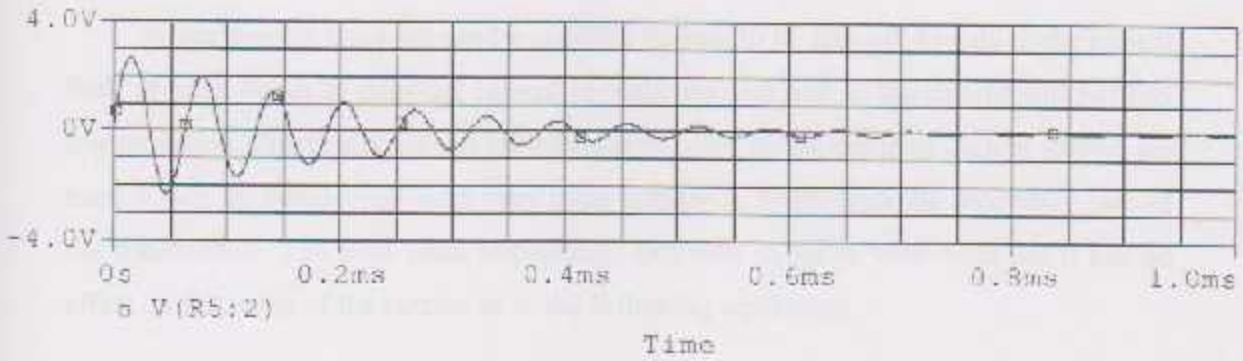

Figure5.7: Oscillation with $\beta < 3$ [12]

If $\beta > 3$, oscillation amplify

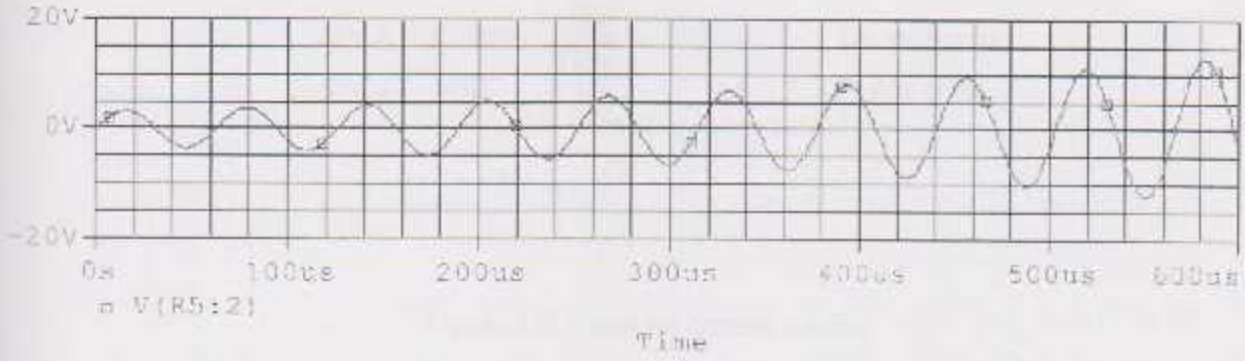

Figure 5.8 : Oscillation with $\beta > 3$ [12]

5.4.2 Constant Current Source

In our project since we need a constant current to be applied directly to the patient limb .It must be an ac constant current to make no pain and so the patient will not feel any sensation. Practically we use transformer to build up the constant current source, we need a step up transformer with very large resistor in series with the secondary side of the transformer. The load (skin impedance) becomes in series with them but it has no effect on the value of the current as in the following equitation:

$I = V_{secondary} / R_1 + R_2 + R_L$

Where;

R_1, R2: in Kilo ohms

R_L: is the skin impedance in ohms.

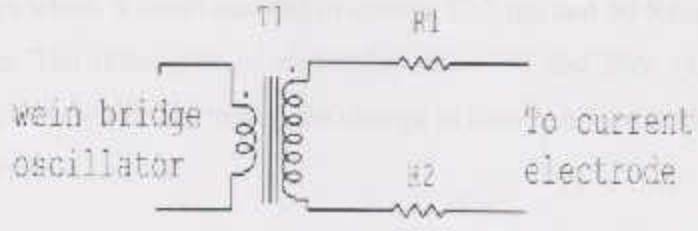

Figure 5.9: Constant current source.

5.4.3 The Electrodes

Types of Electrodes:

1. Surface Electrode (Non-Invasive)
   - ❖ Metal electrode
   - ❖ Suction electrode.
   - ❖ Dry electrode.

2. Needle Electrode (Invasive).
3. Micro electrodes (single cell).
4. Specific ion electrode (PH electrode).

Impedance plethysmography method uses four electrodes in order to do its basic function, the outer pair of these electrodes (Elec (1) and Elec (2)) are called current

electrodes through which a small amount of current (0.2 ma and 50 KHz) are entered to the patient tissue. The other pair of electrodes (Elec (3) and Elec (4)) is called the voltage electrode from which we obtain the change in blood volume or the change of the impedance of the tissue.

In our project we used a special type of ECG electrodes called floating disposable electrode. The principle of this electrode is to practically eliminate movement artifact by avoiding any direct contact of the electrolyte paste or jelly. in general disposable electrodes are of the floating type with simple snap connectors by which the leads , which are reusable are attached .

Chapter Six

Results

In this chapter we will introduce each circuit with actual values and its practical results and waveforms.

6.1 Wien bridge oscillator

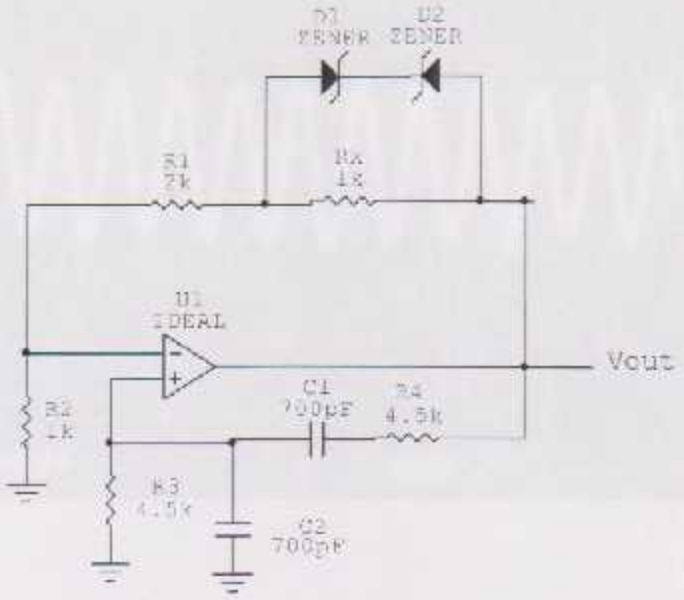

Figure 6.1: Practical wien bridge oscillator [6]

The output for this stage is 4 volt peak to peak.

$C_1=C_2=C=700pF$

$R_3=R_4=4.5K\Omega$

$f_r = 1/2\pi RC = 1/2(3.14)(4.5K\Omega)(700pF)$

$\Rightarrow f_r = 50.6$ KHz .

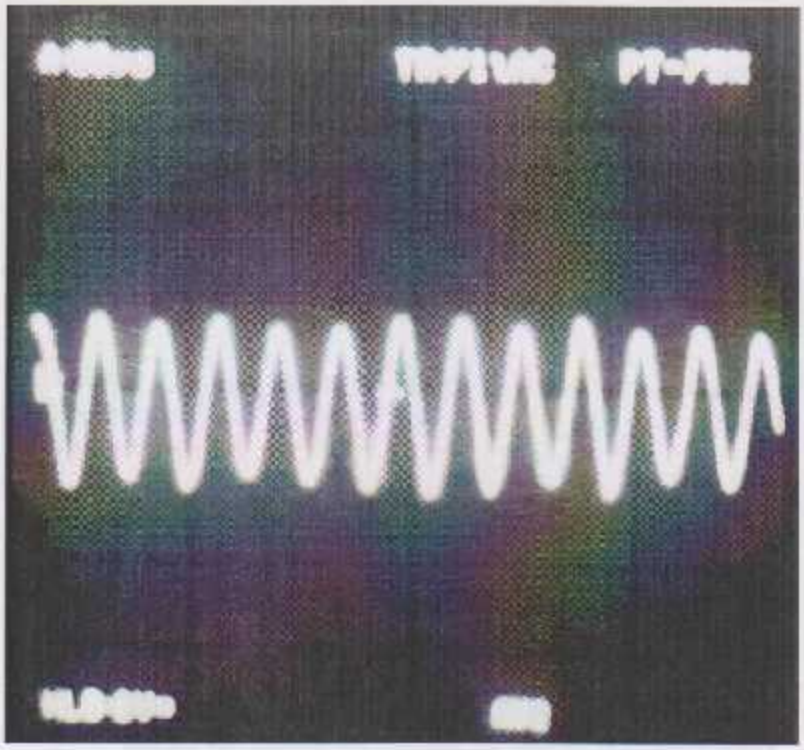

Figure 6.2: Wien bridge oscillator waveform.

6.2 Constant current source

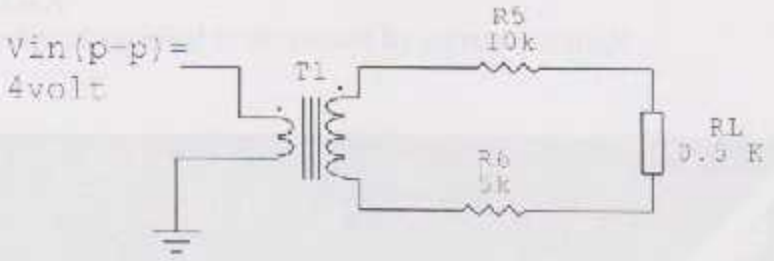

Figure 6.3: Practical constant current source

Vsecondary / Vprimary = a
Where ;
a : is the gain factor
for our transformer a= 10 .
Vsecondary = 10* Vprimary – 10* 4 – 40 volt (peak to peak)

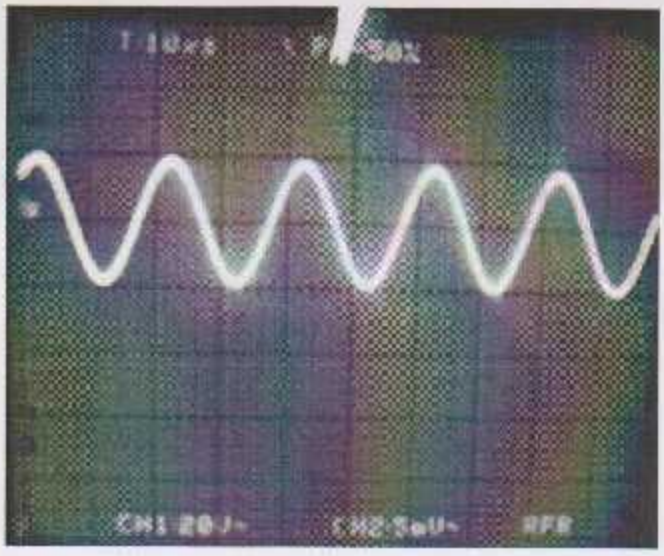

Figure 6.4 : Transformer output waveform

I = Vsecondary /(R_L+15K)
I when R_L – 500 Ω then , Vsecondary = 2*500mV =1 volt
I= 1/ 500Ω = 2 mA
This current is directly applied to the patient by current electrode .

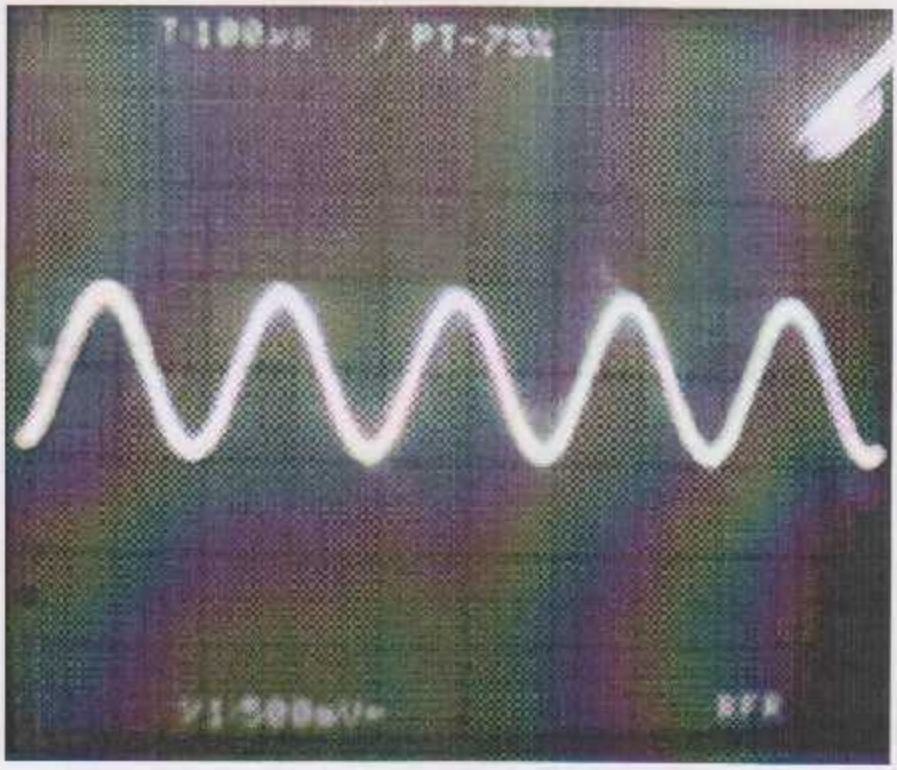

Figure 6.5: Voltage on the500Ω load.

Chapter Seven

Conclusions and future Works

7.1 Conclusions

1. We design a hardware system to detect the bioelectric impedance change of the human limb using impedance Plethysmography technique.

2. The impedance change associated with the blood flowing the limb gives small signal with small change because all of the biological signals are small (in mv).

3. The best position of the electrodes is on the artery path on the arm.

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

5. This part of the project is ended by getting the signal from the voltage electrode and then this signal will be given to another complementary group to determine the cardiac output.

7.2 Future works

1. This system can be developed to be used for diagnostic purposes.

2. The same system can be used to measure another physiological parameter such as respiratory monitoring depending on the volume change of the lung.

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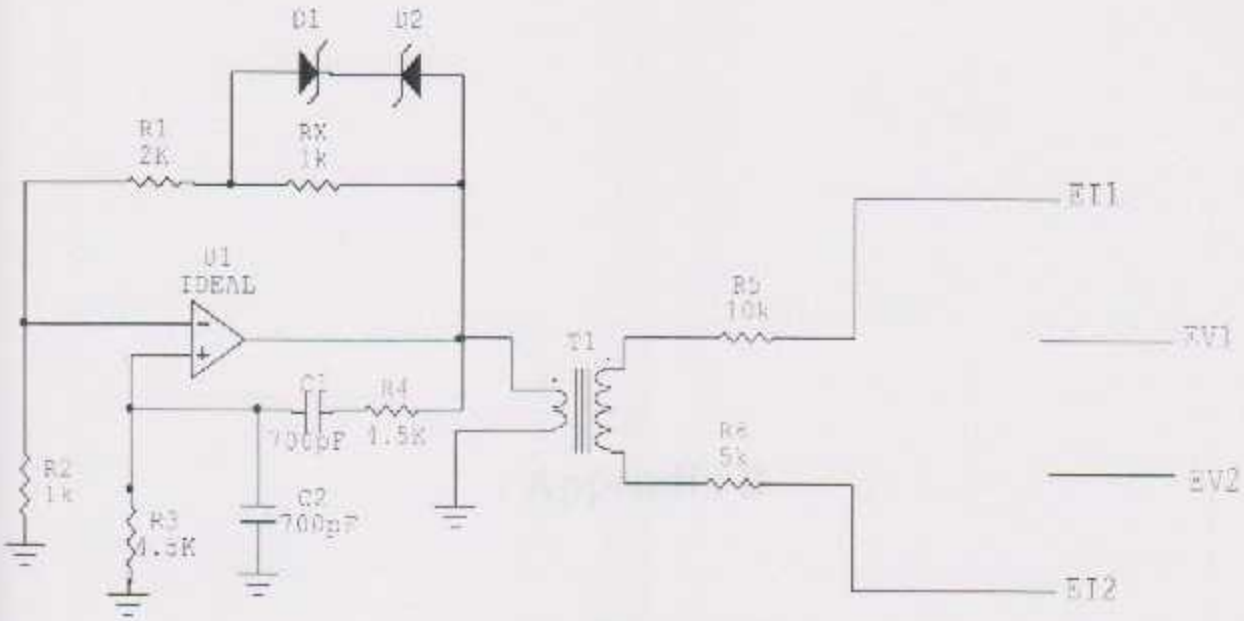
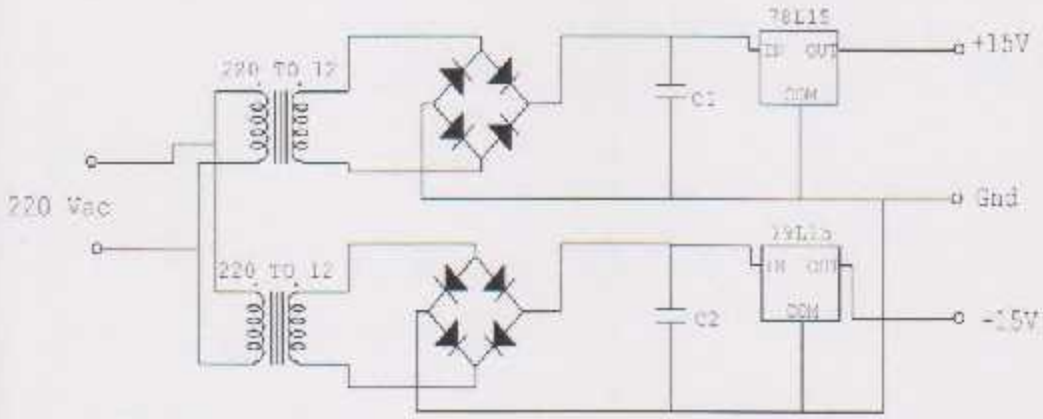
[12] Darren de Ronde,Wien-Bridge Oscillator Circuits. May 15,2002

Appendix A

Circuit Diagram



50KHz Oscillator Coupling Transformer Electrodes



Power supply

Appendix B

قاموس المفردات

The Arabic Meaning of some Words

Word	*Meaning*
Apnea	انقطاع التنفس
Artery	شريان
Assumptions	فرضيات
Blood circulation	الدوره الدمويه
Blood vessel	وعاء دموي
Bone marrow	نخاع العظم
capillaries	الشعيرات الدمويه
Cardiovascular system	الجهاز الدوراني
Clotting	تخثر / تجلط
Coagulation	تخثر / تجلط
Conductor	موصل
Cross section	مقطع عرضي
Diastole	انبساط القلب او تمدد
Elastic	سهل التكيف / مطاط / مرن
Electrical hazard	خطر كهربائي

Flow	تدفق
Homogeneous	متجانس
Impedance	معاوقه / ممانعه
Infants	الاطفال حديثي الولاده
Inspiration	شهيق
Interstitial fluid	سائل خلالي / واقع بين الفرجات
Intracellular	بين خلوي
Invasive method	طريقه تحتاج الى جراحه
Limb	عضو / طرف (قدم , يد)
Lung	رئه
Metabolism	أيض / تفاعل حيوي
Muscles	عضلات
Non-invasive method	طريقه لا تحتاج الى جراحه
Nucleus	نواه
Organ	عضو
Oscillator	مولد موجه متذبذبه
Plethysmography	التغير في الحجم

Probe	مسبار
solute	مذاب
Vein	وريد
Systole	انقباض القلب
Stimulation	تحفيز
Volume	حجم
Thorax	الصدر
Respiration	تنفس
Uterine contraction	انقباض الرحم

Appendix C

Appreviations

Appreviation	Total word
BEI	Bioelectric Impedance
RBC	Red Blood Cell
WBC	Wight Blood Cell
Hgb	Hemoglobin
AC	Alternative Current
?Z	Impedance Change
ECG	Electrocardiogram
PCG	Phonocardiogram
IHG	Impedance Histogram
EHG	Electro Histogram
RF	Radio Frequency

Appendix D

Data Sheet

National Semiconductor

August 2000

LM741
Operational Amplifier

General Description

The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

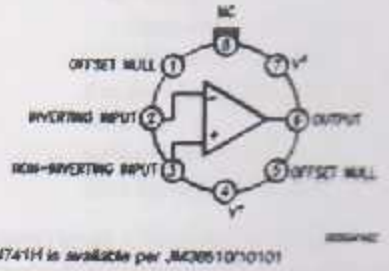
The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM741C is identical to the LM741/LM741A except that the LM741C has their performance guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Features

Connection Diagrams

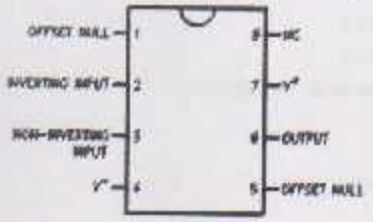
Metal Can Package



Note 1: LM741H is available per JM38510/10101

Order Number LM741H, LM741H/883 (Note 1), **LM741AH/883 or LM741CH**
See NS Package Number H08C

Dual-In-Line or S.O. Package



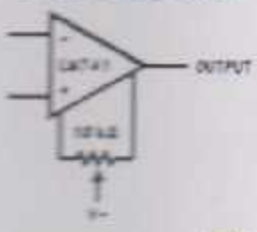
Order Number LM741J, LM741J/883, LM741CN
See NS Package Number J08A, M08A or N08E

Ceramic Flatpak

Order Number LM741W/883
See NS Package Number W10A

Typical Application

Offset Nulling Circuit



Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

(Note 7)

	LM741A	LM741	LM741C
Supply Voltage	±22V	±22V	±18V
Power Dissipation (Note 3)	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage (Note 4)	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous
Operating Temperature Range	−55°C to +125°C	−55°C to +125°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Junction Temperature	150°C	150°C	100°C
Soldering Information			
N-Package (10 seconds)	260°C	260°C	260°C
J- or H-Package (10 seconds)	300°C	300°C	300°C
M-Package			
Vapor Phase (60 seconds)	215°C	215°C	215°C
Infrared (15 seconds)	215°C	215°C	215°C
See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.			
ESD Tolerance (Note 8)	400V	400V	400V

Electrical Characteristics (Note 5)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25°C$										
	$R_S \le 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \le 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \le T_A \le T_{AMAX}$										
	$R_S \le 50\Omega$			4.0							mV
	$R_S \le 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							µV/°C
Input Offset Voltage Adjustment Range	$T_A = 25°C$, $V_S = \pm 20V$	±10				±15			±15		mV
Input Offset Current	$T_A = 25°C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/°C
Input Bias Current	$T_A = 25°C$		30	80		80	500		80	500	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$			0.210			1.5			0.8	µA
Input Resistance	$T_A = 25°C$, $V_S = \pm 20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \le T_A \le T_{AMAX}$, $V_S = \pm 20V$	0.5									MΩ
Input Voltage Range	$T_A = 25°C$							±12	±13		V
	$T_{AMIN} \le T_A \le T_{AMAX}$				±12	±13					V

Electrical Characteristics (Note 5) (Continued)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain	$T_A = 25°C$, $R_L \geq 2\ k\Omega$										
	$V_S = \pm 20V$, $V_O = \pm 15V$	50									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				50	200		20	200		V/mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$,										
	$R_L \geq 2\ k\Omega$,										
	$V_S = \pm 20V$, $V_O = \pm 15V$	32									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				25			15			V/mV
	$V_S = \pm 5V$, $V_O = \pm 2V$	10									V/mV
Output Voltage Swing	$V_S = \pm 20V$										
	$R_L \geq 10\ k\Omega$	±16									V
	$R_L \geq 2\ k\Omega$	±15									V
	$V_S = \pm 15V$										
	$R_L \geq 10\ k\Omega$				±12	±14		±12	±14		V
	$R_L \geq 2\ k\Omega$				±10	±13		±10	±13		V
Output Short Circuit	$T_A = 25°C$	10	25	35		25			25		mA
Current	$T_{AMIN} \leq T_A \leq T_{AMAX}$	10		40							mA
Common-Mode	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
Rejection Ratio	$R_S \leq 10\ k\Omega$, $V_{CM} = \pm 12V$				70	90		70	90		dB
	$R_S \leq 50\Omega$, $V_{CM} = \pm 12V$	80	95								dB
Supply Voltage Rejection	$T_{AMIN} \leq T_A \leq T_{AMAX}$,										
Ratio	$V_S = \pm 20V$ to $V_S = \pm 5V$										
	$R_S \leq 50\Omega$	86	96								dB
	$R_S \leq 10\ k\Omega$				77	96		77	96		dB
Transient Response	$T_A = 25°C$, Unity Gain										
Rise Time			0.25	0.8		0.3			0.3		µs
Overshoot			6.0	20		5			5		%
Bandwidth (Note 6)	$T_A = 25°C$	0.437	1.5								MHz
Slew Rate	$T_A = 25°C$, Unity Gain	0.3	0.7			0.5			0.5		V/µs
Supply Current	$T_A = 25°C$					1.7	2.8		1.7	2.8	mA
Power Consumption	$T_A = 25°C$										
	$V_S = \pm 20V$		80	150							mW
	$V_S = \pm 15V$					50	85		50	85	mW
LM741A	$V_S = \pm 20V$										
	$T_A = T_{AMIN}$			165							mW
	$T_A = T_{AMAX}$			135							mW
LM741	$V_S = \pm 15V$										
	$T_A = T_{AMIN}$					60	100				mW
	$T_A = T_{AMAX}$					45	75				mW

Note 2: "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

Electrical Characteristics (Note 5) (Continued)

Note 3: For operation at elevated temperatures, these devices must be derated based on thermal resistance, and T_j max. (listed under "Absolute Maximum Ratings"). $T_j = T_A + (\theta_{jA} P_D)$.

Thermal Resistance	Cerdip (J)	DIP (N)	HO8 (H)	SO-8 (M)
θ_{jA} (Junction to Ambient)	100°C/W	100°C/W	170°C/W	195°C/W
θ_{jC} (Junction to Case)	N/A	N/A	25°C/W	N/A

Note 4: For supply voltages less than ±18V, the absolute maximum input voltage is equal to the supply voltage.

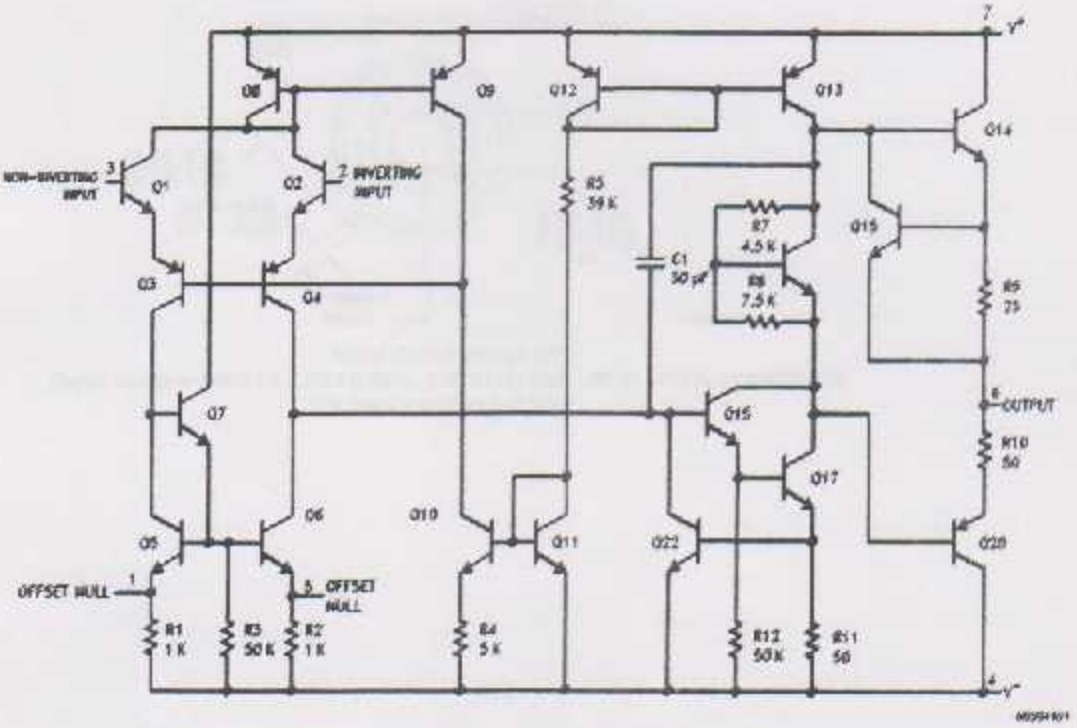
Note 5: Unless otherwise specified, these specifications apply for V_S = ±15V, −55°C ≤ T_A ≤ +125°C (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to 0°C ≤ T_A ≤ +70°C.

Note 6: Calculated value from: BW (MHz) = 0.35/Rise Time(μs).

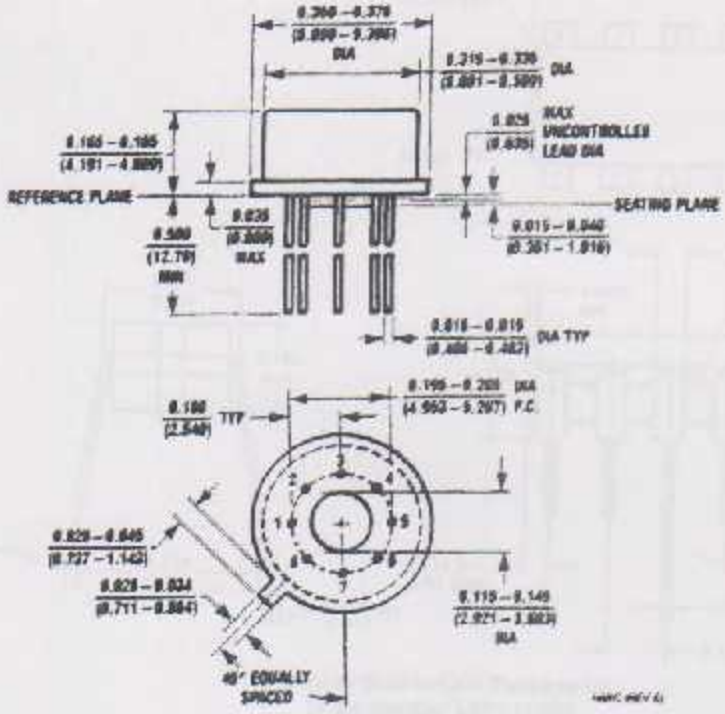
Note 7: For military specifications see RETS741X for LM741 and RETS741AX for LM741A.

Note 8: Human body model, 1.5 kΩ in series with 100 pF.

Schematic Diagram

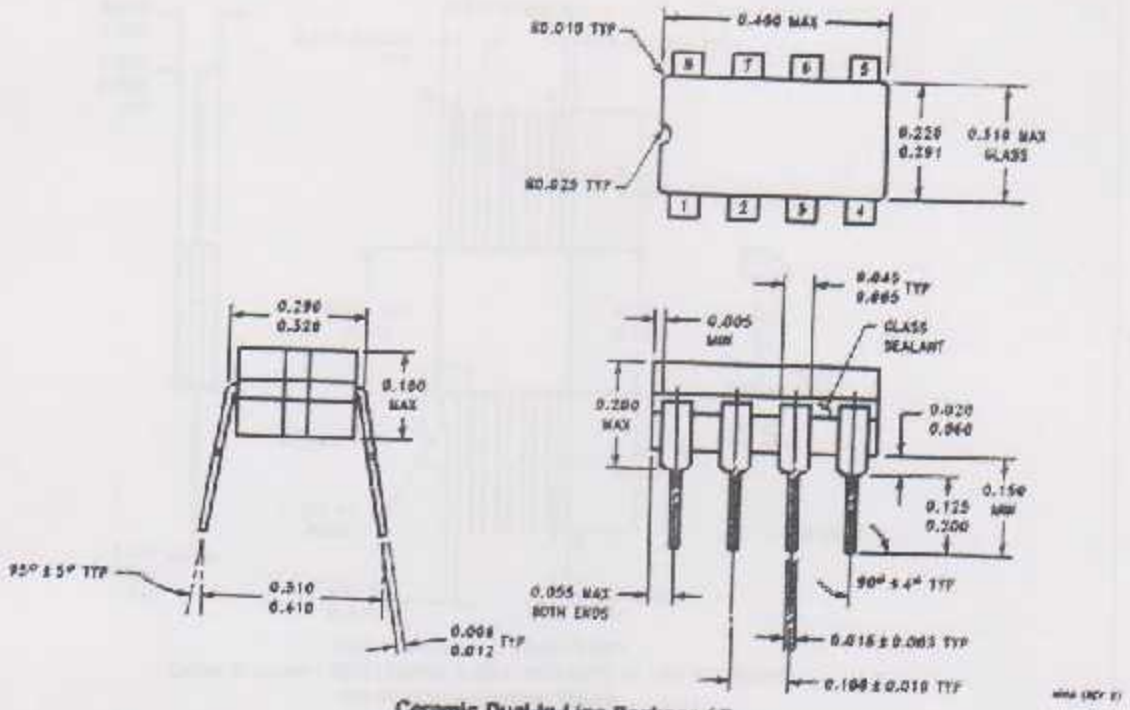


Physical Dimensions inches (millimeters)
unless otherwise noted

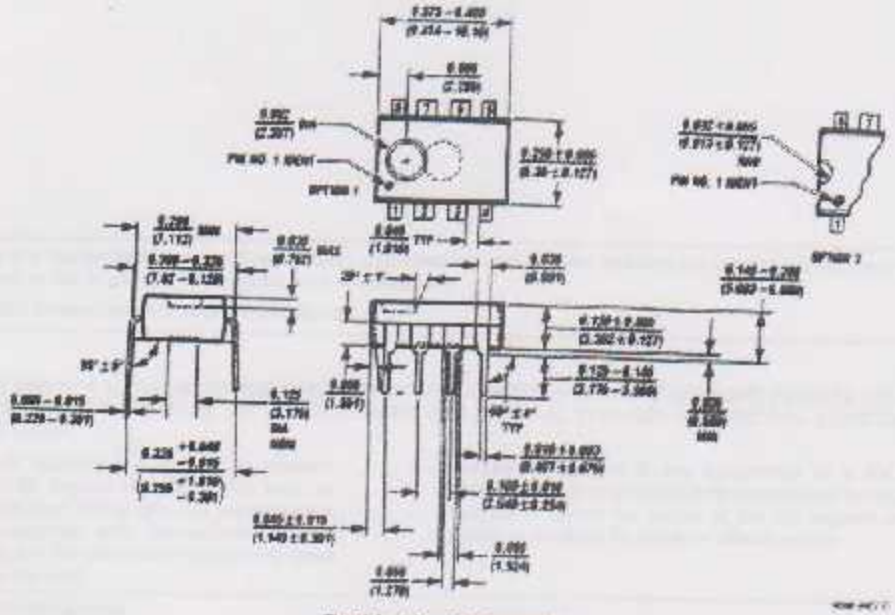


Metal Can Package (H)
Order Number LM741H, LM741H/883, LM741AH/883, LM741AH-MIL or LM741CH
NS Package Number H08C

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

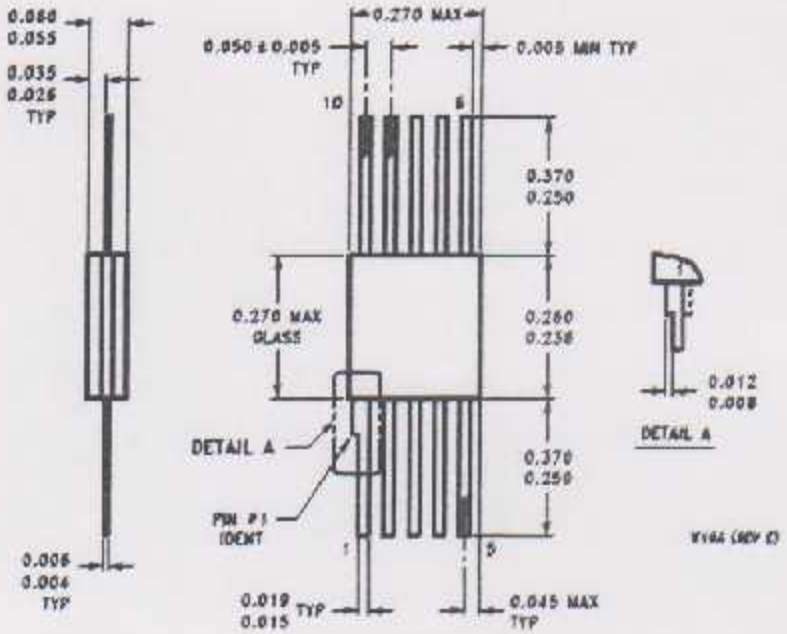


Ceramic Dual-In-Line Package (J)
Order Number LM741J/883
NS Package Number J08A



Dual-In-Line Package (N)
Order Number LM741CN
NS Package Number N08E

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



10-Lead Ceramic Flatpak (W)
Order Number LM741W/883, LM741WG-MPR or LM741WG/883
NS Package Number W10A