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NEW CIRCUIT DESIGN TO MEASURE IMPEDANCE CARDIOGRAPHY (ICG)

Abstract

Impedance plethysmography of the thoracic region, commonly known as impedance cardiography (ICG), and will design a simple electronic circuit to measure this signal that provide us to calculate and measure many medical parameter such as cardiac output ,pulse rate and stroke volume ..

Keywords: As impedance cardiography (ICG), Delta Z waveform, Stroke volume.

INTRODUCTION

Impedance Cardiography it is a method to measure the changing in the thoracic electrical bioimpedance over the time by using four electrodes the first pair of this electrodes using to enter the low amplitude current in high frequency in the thoracic and the other pair of electrodes uses to measure the voltage changing which comes from the changing in the electrical impedance of thoracic, this changing is proportional to the blood volume and flow velocity .

Importance of ICG

The ICG is none-invasive method and in the general the doctors and patient favor the none invasive methods to measure the homodynamic parameters in addition we can take calculate and measured several medical parameters in the same time like stoke volume, cardiac output and vascular resistance, plus that the ICG is cheaper compare the other methods as example when measure the stroke volume in the thermal dilution method the cost is near to thirty Dollars or more while the ICG cost about six Dollars, over all of the above ICG is a safe method and does not make any risk to the patients, and in the final the result come from ICG is more reliable and accurate relative to the others methods.
Therefore, impedance cardiography is none-invasive, inexpensive and readily applicable to almost anyone, anywhere, at any time.
Principle of Operation

ICG measures changes in the bioimpedance by passes a high frequency, low amplitude and constant magnitude current through thorax .the current is administered through the use of two disposable electrodes and anther two electrodes are used to detect the impedance changes caused by the working of heart as shown in the figure (1.1)

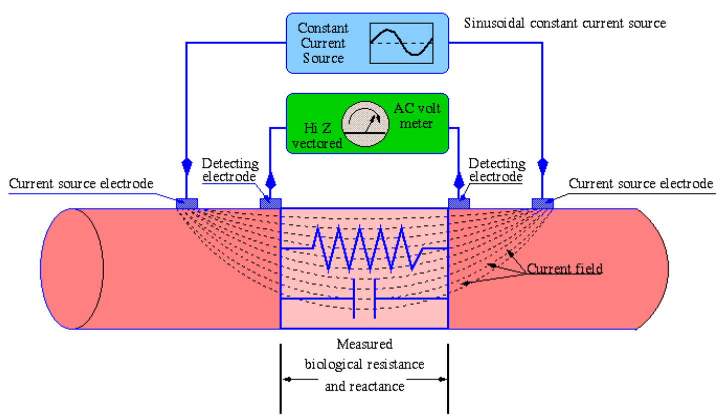

Figure (1.1) shows the four electrodes techniques in ICG

We chose the strip electrode (EL506 for biopac company) which has many good property the main one is it the band electrode which makes the large contract area between the electrode and skin, in addition this property reduces the internal impedance of electrodes and makes the current field enters to the body more uniform which make the result more accurate plus that the current density and concentration is come down so the patient does not feel any irritations or burns.

These electrodes uses to measure the longitudinal impedance of thoracic by entering the current in pair of electrodes which arrange of the outer part, one electrode of these electrodes is placed around the abdomen and the other around the upper part of the neck,And to measure the changing in the voltage We use the other pair of electrodes which arrange of the inner part, one electrode is placed around the thorax at the level of the joint between the Xiphoid and the sternum called Xiphisternal joint and the other around the lower part of the neck and in the figure (1.2) shows the placement of band electrodes inn the measurement of thorax impedance.

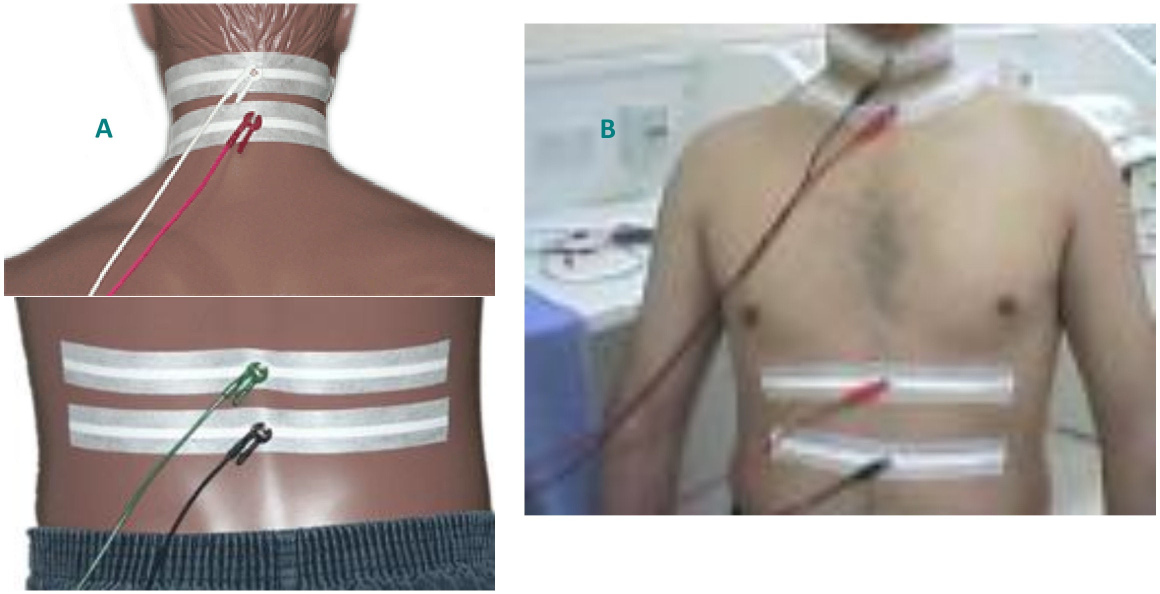

Figure (1.2): (A) Placement of band electrodes in the Back (B) Placement of band electrodes in the Chest (Experiment)

When we use the current in the properties as be described the main component of effect to the bioimpedance is the liquids especially blood and the amount of blood in the thorax changes as a function of the heart cycle. During systole, the right ventricle ejects an amount of blood into the lungs which equals the stroke volume. At the same time blood flows from the lungs to the left atrium. The effect of these changes in the distribution of blood in the **thorax as a function of the** heart cycle can be determined by measuring the impedance changes of the thorax. And the figures (2.1) shows the ideal shape of the delta Z and derivation of it.

Looks like an aortic pressure waveform but there are substantial differences and the IMP-signal (or Delta Z waveform; i.e., change in impedance over time) is a result of the volume and velocity of blood flow in the aorta.

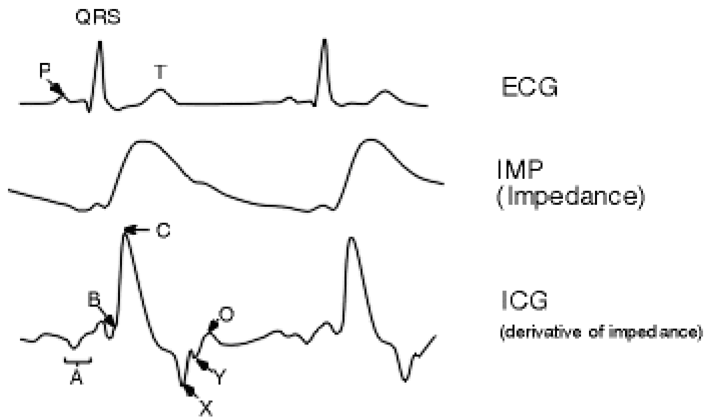

Figure (2.1) The ICG, IMP, and ECG signals Bronzino,2001]

Stroke volume

Stroke volume is the amount of blood pumped by the left ventricle of the heart in one contraction, and the stroke volume is not all of the blood contained in the left ventricle. The heart does not pump all the blood out of the ventricle. Normally, only about two-thirds of the blood in the ventricle is put out with each beat What blood is actually pumped from the left ventricle is the stroke volume and it, together with the heart rate, determines the cardiac output, the output of blood by the heart per minute.

$$SV = \rho_b \frac{l^2}{Z^2} \left|\frac{dZ}{dt}\right|_{\min} \cdot t_e$$

Where

SV = stroke volume [ml/beat]

$\square_b$= resistivity of the blood [□ ·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 [□ /s]

t_e= ejection time [s]

Hardware Design

hardware design details include the electrical specifications of the oscillator and voltage to current converter circuit, amplifiers, envelops detector, and the filters. After that design impedance cardiography simulator in all details to calibrate the ICG signal. the values of the used resistors and capacitors can be calculated, taking in consideration the maximum allowed current passing through the electrical equipment to satisfy the safety conditions of these devices, and not to damage them, and also includes the calculations of the cut off frequencies of the filters.

The circuit is designed to pick up ICG signal, which has many specifications as following:

1. Modulated Signal
2. Very low Amplitude.
3. Frequency content ranges between 0.33 to 24Hz
4. Has an AC and DC component.

The figure 3-1 can be summarize a simple block diagram of the expected system, which mainly consists of an Instrumentation Amplifier, Gain circuitry, Envelop Detector and filters. The arrangement of the block depends only on the implementation of the expected circuit in the lab

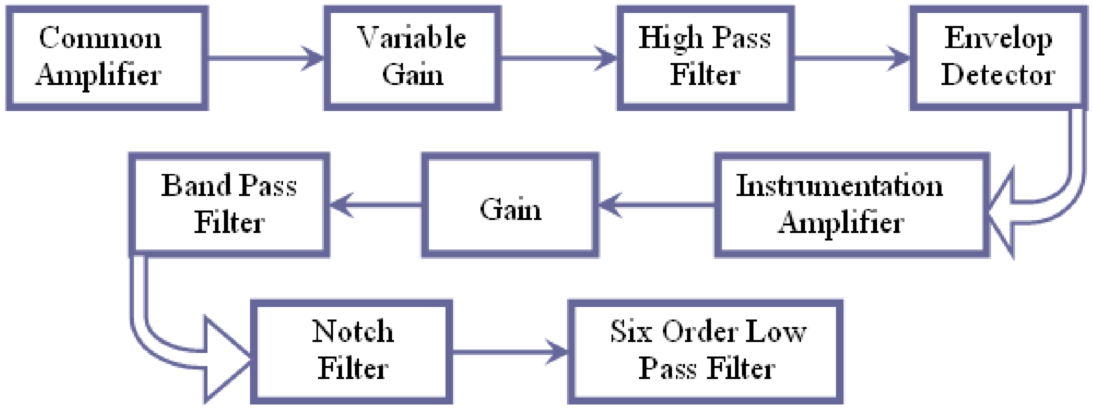

Figure (3.1): Building blocks of the ICG circuit

Signalgenarator

A constant high frequency AC current with very low amplitude (about 4 mA) is injected into the body through two sensors. This current imperceptible by the patient does not have significant physiological effects. And because current is vary danger at human dealing with patient body the most important things in this stage is safety requirement, therefore the design in this circuit is vary accurate.

The figure 3.2 can be summarizing in simple block diagram of the expected design. Which mainly consist of a waveform generator, voltage to current converter, gain circuitry.

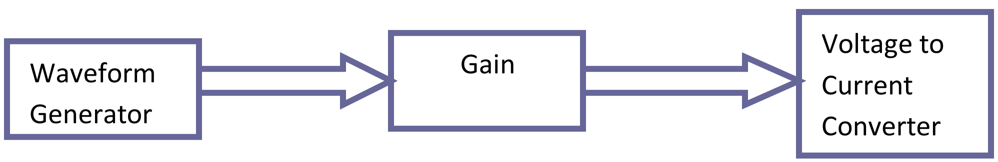

Figure (3.2): Block Diagram of Signal Generator

Results and Recommendations

The output signal of the hard ware design as shown in Fig 4.1 has noises and distortion compared with the desire real ICG signal

Figure (4.1): The ICG Signal from Hardware Circuit

Recommendations

1. Making the hardware in a printed board will make it applicable to be portable, and give the patient the suitable place and more free movement.
2. developed program to measure all parameter by using LabView system.
3. Take many measurement sample from many people and compare between the values of the biological parameters in the traditional ways and the values come from our ICG device to calculate the accuracy and precision.
4. Building the ICG simulator to calibrate the device.
5. Build neural network algorithms that take the ICG signal from patient and compare it with abnormal signal to determine the type of heart decease.
6. Design two stages in hardware circuit, the first stage is optocoupler circuit to produce safety requirements for patient, and the second stage is transient protection circuit to produce safety for the device from defibrillator (DC shock).

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