APPLICATION OF ELECTRONIC TECHNIQUES IN THE ANALYSIS OF SOME PHYSIOLOGICAL PHENOMENA

Thesis

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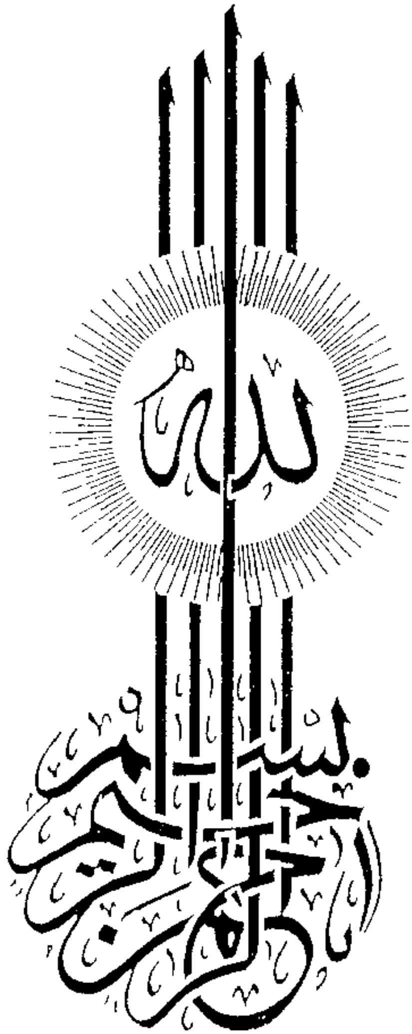
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SUMMARY

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In this thesis the impedance cardiograph for measuring the cardiac stroke volume has been studied. The design and development of such technique are introduced.

Although electrical impedance measurements have been used to study biological systems, further studies are needed to more fully understand the low frequency impedance behaviour of biological specimens.

The purpose of this work is to present an impedance measuring system suitable for such studies. A simple impedance system has been designed and a complete circuit diagram is provided. The main components of the system are a constant current source and a phase sensitive demodulator. The operation of each individual circuit in the measurement system is described.

An experimental evaluation of the designed system using a test specimen composed of standard electrical component, has been carried out. The effect of frequency on the impedance of the specimen has been studied through an equivalent impedance model of the biological specimen.

A theoretical analysis of the impedance variation wave form of the thorax pre and post-operation as a function of time for different subjects suffering from different heart diseases are carried out using computer program.

The time domain of the impedance variation is transfered to frequency domain using Fourier transform.

It was the purpose of this study to compare the frequency spectra obtained from the wave form analysis of the different cases. In addition, the number of harmonic components which still contribute significantly during reconstruction of the analysed signal was determined using the variance percentage (VAR)%.

The results in this thesis could be summarized as follows:

1. The system present here allows rapid measurement of a-c impedance while minimising the influence of undesirable electrode effects.
2. The addition of a variable-frequency driving source would allow impedance measurements over a wide range of frequencies extending up to 500 KHZ.
3. The use of field effect transistor (FET) as input stage of amplifier circuit decrease the electric noise in the measurements, and the Motorla MC 1495 as a phase sensitive demodulator provides versatility to the impedance measurement system.
4. The reactive component of the measured impedance can be determined by shifting the reference signal by 90 degree and adding another demodulator unit to the measurement system.
5. It is also found that in the frequency range from 10 to 100 KHZ, for a standard model ($R = 1\ K\Omega$ and $c = 0.001\ \mu f$), the results obtained experimentally from this circuit agree well with the theoretical values calculated on the basis of the model.

6. At low frequencies of the applied signal, the impedance frequency relation depends on the resistive component constituting the equivalent circuit model.
7. The system has been used successfully on several types of plant specimens.
8. From the values of (VAR) %, it is found that the 99 percent level of coincendense between original and reconstructed wave form for all cases was reached with the 8th to 15th harmonics.
9. The results of calculating (VAR) % showed that the impedance variation curves can be represented sufficiently by the moduli of the first eight harmonics, hence the fourier transform was limited to this level.
10. The shape of the reconstructed impedance wave from using the inverse fourier transform indicates that the eight harmonics gives a fairly good reconstruction.
11. The harmonic contents, in all cases can be used as a characteristic diagnostic features for each case pre-operation.
12. Comparing the harmonic content of all case post-operation with that of the normal case it was clear that they accept values and trend around the normal case.

INTRODUCTION

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The basic function of the heart has been described as a blood pump. The cardiac stroke volume is considered a useful physiological parameter for indicating the efficiency of this pumping action. Information about this function can be used in the detection of heart diseases.

The conventional methods available for measuring cardiac stroke volume are the dye dilution, and the fick principle. These methods are lengthy, and not suitable for all patients.

Kubicek and his colleagues (12) have adapted transthoracic impedance measurements to the investigation of cardiac function. These studies have indicated that upon passage of a sinusoidal current across the chest there are impedance changes which are synchronus with the cardiac cycle.

Many investigator have used the impedance method in determination of cardiac stroke volume as well as investigating different physiological parameters other than cardiac stroke volume. However, no work has been done in investigating and analysing the impedance variation waveform of the chest.

The aim of this thesis is to design an electrical impedance measuring system which is simple to use and easy to construct. An equivalent circuit model will be developed to test system and explain the results.

Besides, a mathematical model will be suggested to analyse the impedance variation waveform of the chest of different patients suffering from different heart diseases.

The model will be adopted on the basis of the transformation of the impedance-time relation from the time domain into the frequency domain using Fourier transform. The impedance variation of all cases are analysed in which the periodic time and frequency contents are highly specified for each case. Also, the number of harmonic components necessary for sufficient reconstruction of the analysed wave form will be determined by calculating the variance percentage.

A designed computer program will be used for calculating the suggesting analytical model.

The analysis can be extended to deduce the first derivative of the impedance wave form for the purpose of calculating the cardiac stroke volume.

The measuring system that has been constructed and the experimental work as well as the theoretical analysis are discussed in the following chapters after a review of the work that has already been done.

CHAPTER (I)

IMPEDANCE TECHNIQUES AND, CARDIAC OUTPUT MEASUREMENTS

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1.1. CARDIAC OUTPUT MEASUREMENTS

During the last few years many attempts have been made to relate observed electrical impedance changes of the thorax occurring during the cardiac cycle to measure the cardiac output. The impedance technique has developed as a result of the investigations. The technique permits measurement of stroke volume and cardiac output which are considered the standard cardiac parameters to measure.

Nyboer (15) was the first experimenter to apply the impedance technique. By supplying an alternating constant current to the thorax, and measuring the potential difference developed across some portion of the thorax, the impedance was measured. A cyclic variation of impedance was discovered, coincident with the heart cycle as shown in Fig. (1.1).

Many experiments were undertaken, and a theoretical relationship between the stroke volume , ΔV, of the heart and the impedance variation was derived as

$$\Delta V = - \frac{\Delta Z}{Z_0} \cdot V_0 \qquad (1.1)$$

where Z_0 was the mean measured impedance of the thorax, and ΔZ was the change in thorax impedance.

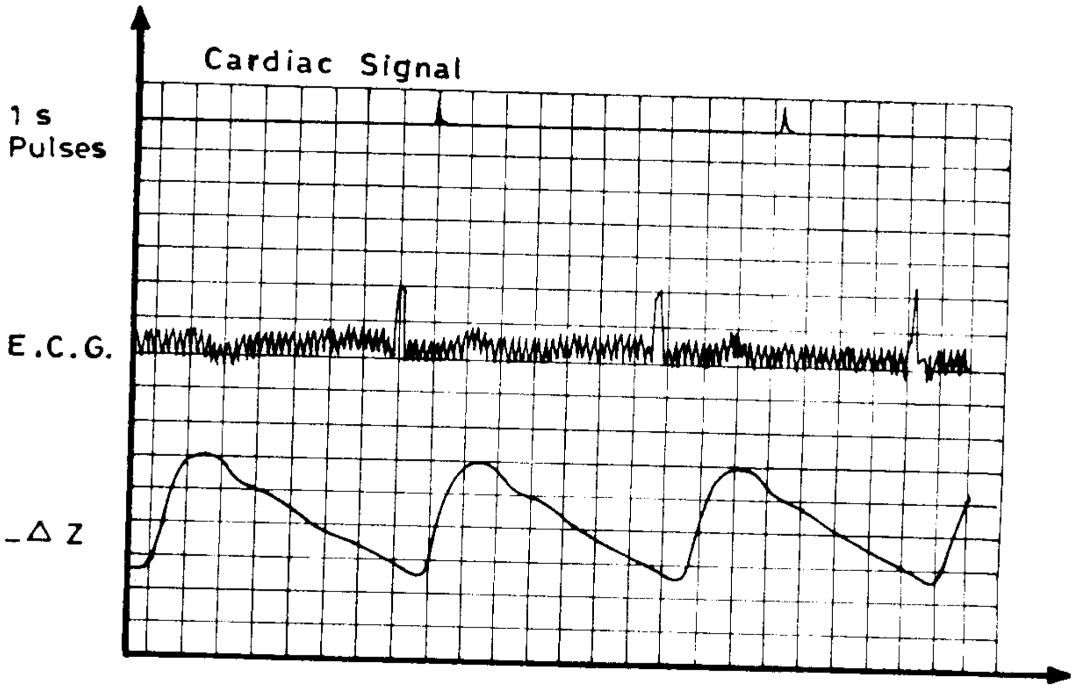

Fig.(1_1).