Design And Implementation Of A Biomedical Signals Generator Based On Microcontroller

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Abstract :

Biomedical signals are one of the most important parameters in the diagnosis, so the doctors and clinical trainers must be familiar with these signals. Biomedical signals generator is an electronic device used to simulate such signals for the above mentioned purpose. The biomedical signals generator (BIO-SG) is a useful tool for biomedical signals devices for calibration , monitoring and incorporate in educational tasks and clinical environments. a biomedical signals generator based on microcontroller and also we use a digital to analog convertor and an amplifier to act as a conditioning circuit for the signal and made it easy to show on an oscilloscope. The device is based on a microcontroller to generate the basic ECG wave and EMG wave, these signals can used as an input to the ECG and EMG machines. the results shows that the generated waves with low error rate compared with the biomedical standard waves.

Keywords: ECG , EMG, Microcontroller, biomedical signals .

تصميم وتنفيذ مولد أشارات حيوية بالاعتماد على المسيطر الدقيق

ابراهيم عامر ابراهيم فادية نوري حمادي قيصر أياد أحمد
كلية الهندسة الخوارزمي / جامعة بغداد
قسم هندسة الطب الحياتي

الخلاصة :

الإشارات الطبية الحيوية هي واحدة من أهم المعايير في التشخيص، وبالتالي فإن الأطباء والمدربين السريرين يجب أن يكونوا على دراية مع هذه الإشارات. مولد الإشارات الطبية الحيوية هو جهاز إلكتروني يستخدم لمحاكاة مثل هذه الإشارات لغرض المذكورة وهو أداة مفيدة للأجهزة الطبية الحيوية لرصد إشاراتها للمعايرة وتدرج في المهام التعليمية والبيئات السريرية. مولد الإشارات الطبية الحيوية يعتمد على متحكم وأيضا نستخدم المحول الرقمي التناظري إلى ومكبر للإشارات ليكون بمثابة دائرة تكييف للإشارة، وجعل من السهل أن تظهر على راسم الذبذبات. ويستند الجهاز على متحكم ليولد الأساسية ECG موجة وموجة EMG، يمكن استخدام هذه الإشارات كمدخل للآلات ECG وEMG. النتائج تظهر أن الموجات المتولدة مع نسبة الخطأ منخفضة مقارنة مع مستوى موجات الطبية الحيوية القياسية.

1. INTRODUCTION

Biomedical signals are observations of physiological activities of organisms, ranging from gene and protein sequences, to neural and cardiac rhythms, to tissue and organ images. Biomedical signal processing aims at extracting significant information from biomedical signals. With the aid of biomedical signal processing, biologists can discover new biology and physicians can monitor distinct illnesses. [1]

A signal resembling the actual ECG or EMG is required in order to develop, and service biomedical signals measurements equipments. So the tests were made on humans. This is very unethical. The biomedical signals generator is a device that can used to test the equipments instead. It removes the potential risk to the test subject. [2]

The biomedical signals generator described here produces suitable artificial signals. These signals are fed to the ECG or EMG equipments which are to be tested. [3] The industrial biomedical signals simulator is rather expensive or is not manufactured with our standards and our environments. So, the purpose of the project is to design a biomedical signals generator which uses a microcontroller chip and a network of capacitors, resistors to generate the signals, which will be less expensive and easily available. Our objective was to make the biomedical signals generator for generated the basic ECG and EMG waves.

Electrocardiogram (ECG) is a graphic recording of the electrical potentials rhythmically produced by the heart muscle. Physicians record the ECG very easily and non invasively by placing electrodes in different places of the body .ECG is used for clinical diagnosis and monitoring the heart for abnormality. [4] Electromyography (EMG) referred to as myoelectric activity, measures the electrical impulse of muscles at rest and during contraction. it is a small electrical currents are generated by muscle fibers prior to the production of muscle force. These currents are generated by the exchange of ions across muscle fiber membranes, a part of the signaling process for the muscle fibers to contract. The signal called the electromyogram (EMG) can be measured by applying conductive elements or electrodes to the skin surface, or invasively within the muscle. [5, 7, 8]

The paper is organized as follow:

1. Design of a low cost interactive biomedical signals generator.
2. It’s useful for training doctors and clinical operators on reading the biomedical signals.
3. Replace the person by a biomedical signal generator in cases of biomedical measurements devices.

The following sections give the detailed for the entire project. Section two described the human heart and the skeletal muscles, a detailed discussion about the ECG wave, its intervals and duration of its signals. Also a detailed description of the physiology of the skeletal muscles is mentioned. While in section three deals with the implementation and design of the project with its block diagram and the description of the hardware components used, like a microcontroller and the other components. We will discuss the experimental results in section four where it contain a detailed description of the progress made with pictures of the waves generated.

2. THEORETICAL BACKGROUND

2.1. Electrocardiogram (ECG): [4]

The most functional indicator of the cardiac activity is the is the electrocardiogram (ECG). The ECG is used around the world as a simple non invasive way for diagnosis heart conditions. The rhythmical behavior of the heart can be monitored and used as a diagnostic tool to detect heart abnormalities by acquiring the electrical activity on the body surface, across the heart. This electrical activity originates from the electrical activation of muscles in the heart, causing mechanical motion. Adhesive electrodes applied to the chest and limbs connect to the electrograph machine that detects patterns of minute electric currents in the heart muscle and print it on a chart or display it on a screen. The test dose not hurt nor does it have any side effects. It does not require any preparation. The recording takes few seconds only. An ECG can be used to asses if the patient has had a heart attack or evidence of a previous heart attack. The doctor can determine the nature of an erratic heartbeat.

The electric potentials generated by the heart appear throughout the body and can be measured across its surface. The typical ECG waveform is shown in **Figure (1).** The signal is characterized by five peaks and valleys labeled with the successive letters PQRST and U.

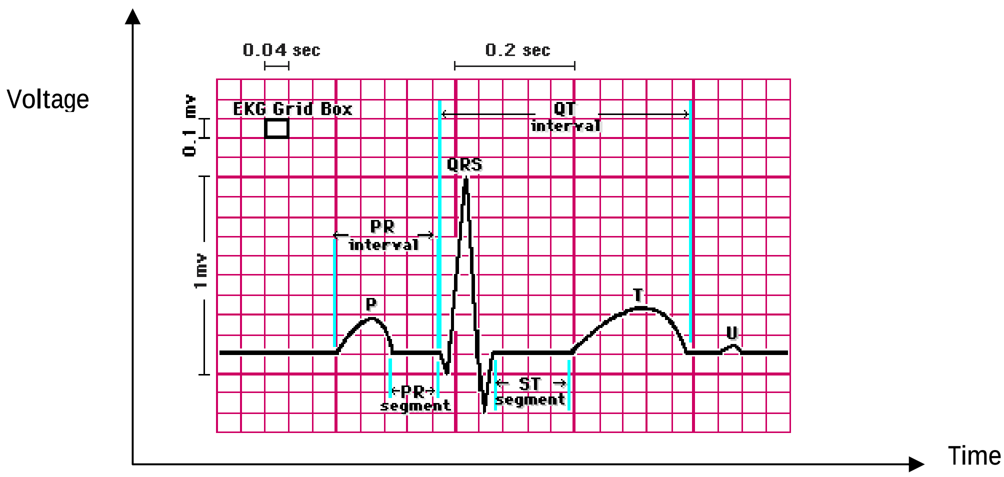

Fig. (1) The waves and intervals of the ECG wave

2.2. Electromyography (EMG): [7]

Skeletal muscle contraction is controlled by motor nerves that synapse with the muscle fibers. In general each fiber has one synapse, innervated by one motor neuron. The neuromuscular synapse is often called the motor end-plate.

At the end-plate a motor neuron axon branch penetrates into a small depression on the muscle fiber surface.

The axon terminal contains many mitochondria and acetylcholine (ACh) – containing synaptic vesicles. The postsynaptic muscle fiber plasma membrane is highly folded and contains high concentrations of ACh receptors (**Figure. 2).**

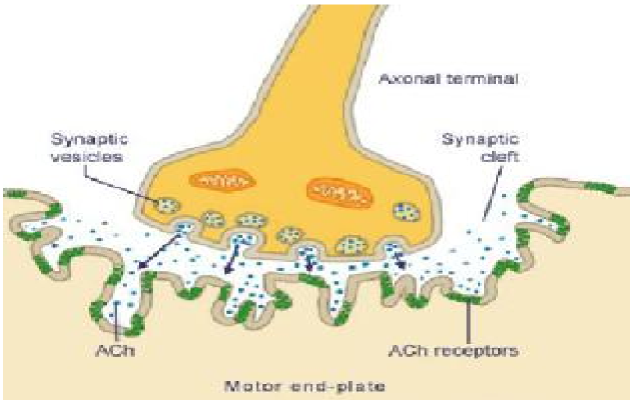

Fig. (2) Neuromuscular synapse.

Neuromuscular transmission An action potential traveling down the axon invades the synaptic terminal. Synaptic vesicles fuse with presynaptic membrane releasing ACh. ACh diffuses across synaptic cleft and binds to ACh receptors on post-synaptic (muscle) membrane, causing local depolarization (end-plate potential). Local depolarization initiates an action potential that travels the length of the muscle fiber and invades the interior along the T tubes. The events that link the electrical activity (action potential) of an excited muscle fiber with the contractile activity of the sarcomeric contractile proteins are termed excitation-contraction (E-C) coupling.

3. DESIGN AND IMPLEMENTATION OF THE (BIO-SG)

3.1. The Design of the BIO-SG:

To accomplish the above requirements and features. The design of the system (BIO-SG) must be good, easy and simple to get vital signs generator according to the approved specifications above.

That design of the device consists of three phases, namely: -

1 - processor for electronic (digital) signal generation and processes. microcontroller was chosen to do so. (PIC16F887) microcontroller was suitable quality and available and easy to use and programming.

2 - adapter digital signals to analog (MC 1408), so that the user can view and use the generated signals physically.

3 - amplifier signals for strong signals and gives high reliability of the signals generated.

The block diagram of the system in **Figure (3)** explaining the stages of process of generating the bio-signals is shown below:

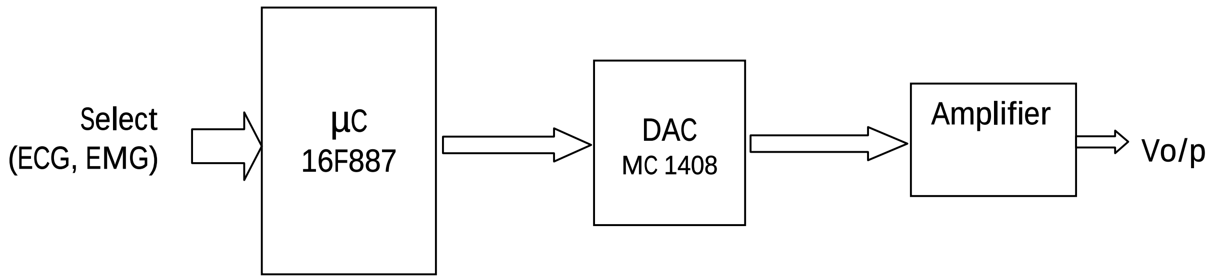

Fig. (3) The block diagram of the system(BIO-SG).

The basic idea of this project is to take standard Biomedical signals and then processed and stored in the memory of a microcontroller and then displayed on the exits on-demand coming from the user of the device (if it ECG or EMG) after treatment and enlarge in the other phases and make it signals a vital with reliable high.

It is obviously the possibility of the microcontroller in terms of capabilities and capacity. Where we choose the Model PIC16F887 between their most types, in which the PIC16F887 is one of the latest products of *Microchip*. It features all the components which upgraded microcontrollers normally have. For its low price, wide range of application, high quality and easy availability, it is an ideal solution in applications such as: control of different processes in industry, machine control device, measurement of different values etc.

The scheme flowchart has been designed which shown in the figure (4) , writing a program to control the microcontroller and execute commands as planned and then stored inside the microcontroller.

The data signals which were outputted from the microcontroller are in a digital form.

So we were used the digital to analog convertor (DAC) to convert these digital output signals into an analog form. Here we were used the (MC 1408) digital to analog convertor to do this job , this (DAC) has many useful features that it made us chooses it.

The output of the (DAC) was a current that follow the relation:

$$I_o= (+Vref/R1)[(A1/2)+(A2/4)+(A3/8)+(A4/16)+(A5/32)+(A6/64)+(A7/128)+(A8/256)]$$

Or

$$I_o= (+Vref/R1)(N/256) \quad \ldots\ldots(1)$$

The output current signal (Io) must be converted to voltage signal , therefore we need to use a current to voltage converter at the output of the DAC in order to feed the output signals to the next stages .

To make sure that the design of the BIO-SG was well and in conformity with the specifications and compared with other biomedical signals generators devices in terms of matching and calibration of biomedical signals generated. Used a formula errors in equation (2 & 3) to calculate the percentage of errors in the biomedical signals generated separately (for ECG and EMG).

Error = error + √((Standard Signal (i)-Generated Signal(i))*(Standard Signal (i)-Generated Signal(i)) ………………………………………………………………………… (2)

Where i=1 to maximum length of the signal in samples.

Error = error / signal length in samples……………………………………… (3)

And then modify the design to match the standards accepted and approved in the calculation errors of biomedical signals generated from our system.

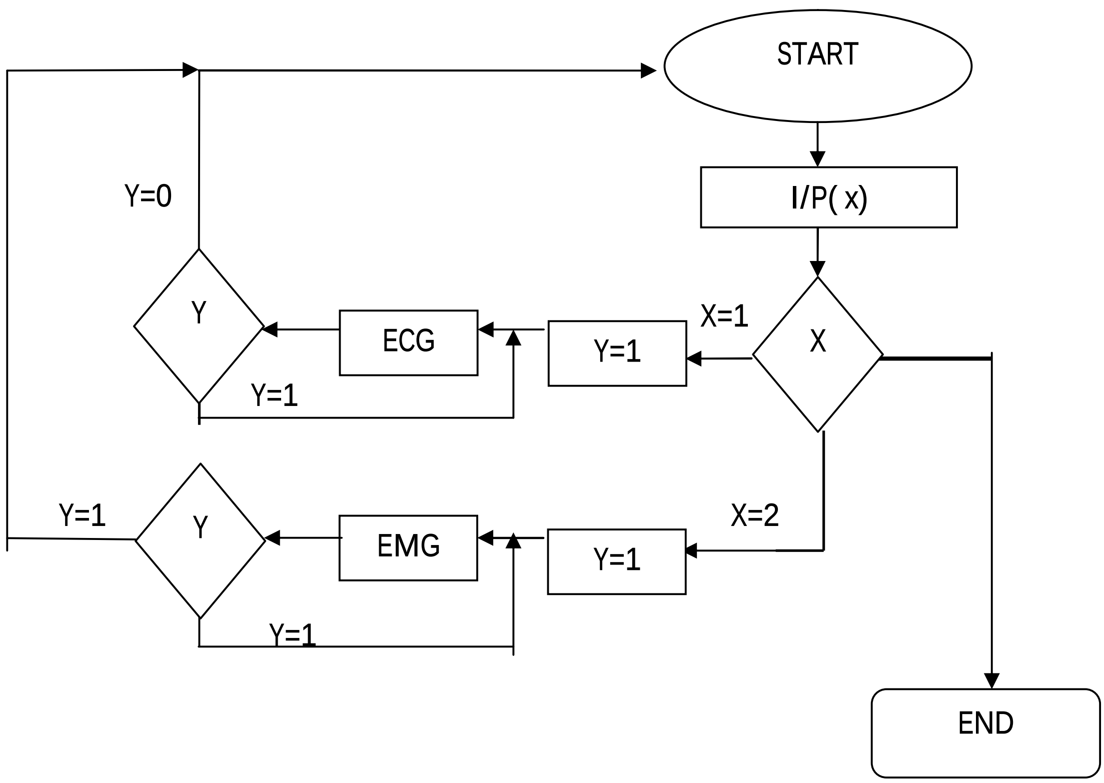

Fig. (4) Bio-SG flow chart

3.2.The Implementation of the BIO-SG

3.2.1. Components used:

1. 16F887 microcontroller.
2. DAC MC1408L8.
3. 741 Amps.

4. Push button.
5. 1KΩ, 3.9KΩ, 2.2KΩ resisters.
6. (30nf & 15pf) capacitors.

3.2.2. Generation Biomedical signals:

In this part we will present the generating of biomedical signals, to generate these signals we use the circuit shown in the **Figure (5).**

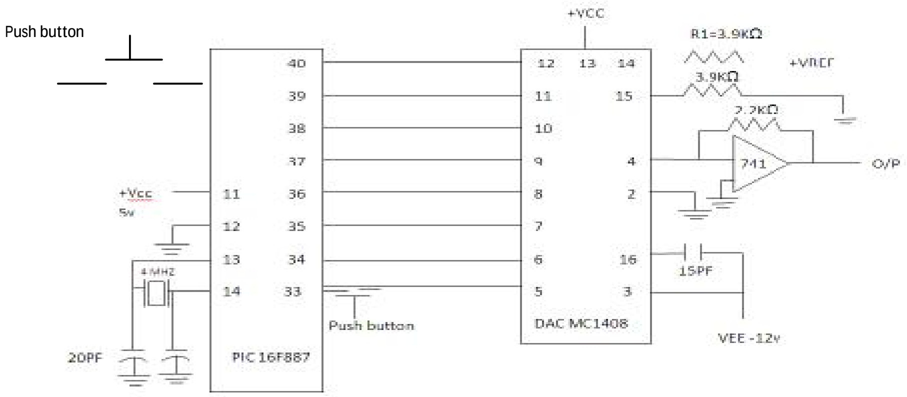

Fig. (5) circuit diagram of biomedical signals generator BIO-SG

The idea of generating biomedical signals is simply done in four steps:-

The First Step : It was taking a biomedical signals from a standard biomedical signals generator device that generates standard biomedical signals which is the Biopac Student Lab PRO 3.7 version 9/9/2010. Where signals were taken from someone in good health (aged 23 years and 70 kilograms weight and length of 185 cm) stored in the Biopac Student Lab PRO 3.7 device.

We was chosen two types of biomedical signals (ECG and EMG) where:-

- For ECG signal : taking one cycle of a series of constriction and extroversion indicated heart muscle as it is in the figure (6). It was a digital signal with a number of 325 sample and sample rate of 6000 bit/second. That each sample consists of 8 - digital units (bit) as stored in the Biopac Student Lab PRO 3.7 device.
- For EMG signal :Also taking one cycle of a series of constriction and extroversion indicated hand muscle (Brachioradials) as it is in the figure (7). It was a digital signal with a number of 186 sample and sample rate of 6000 bit/second. That each sample consists of 8 - digital units (bit) as stored in the Biopac Student Lab PRO 3.7 device.

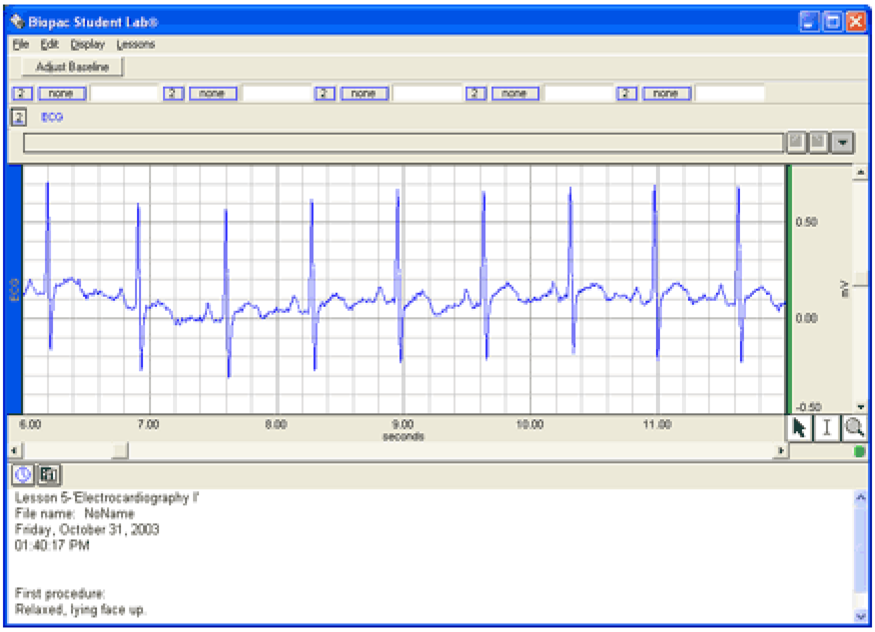

Fig. (6) The ECG signal as stored in the Biopac Student Lab PRO 3.7 device.

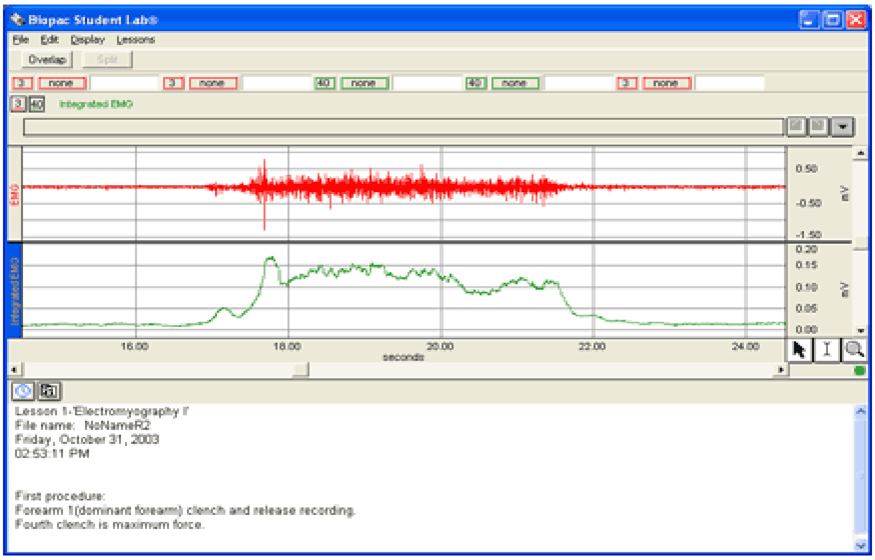

Fig. (7) The EMG signal as stored in the Biopac Student Lab PRO 3.7 device.

The Second Step : We were processing, classification and order biomedical signals taken from the Biopac Student Lab PRO 3.7 device to conform with the requirements of the electronic circuits used in the system and then stored in the memory of the 16F887 microcontroller.

And also to write a program to control the processes and steps of the system and then also stored in controlling the memory of the 16F887 microcontroller due to the flow chart shown in the **Figure(4).**

Program was written by using micro C programming language and storage the required biomedical data using IC programming kit from microelectronika company.

The Third Step : is in this step we processing the data signal outputted from the 16F887 microcontroller due to the demand given to him from the user (Are they ECG signal or EMG signal) and this information will be in the digital signals form, so it must be converted into analog signals and then amplified and rehabilitation to be reliable and credible and high quality and taken out of the BIO-SG device.

The Fourth Step : We used and employment the MATLAB programs to calculate the harmonics Map for standard biomedical signals using fast Fourier transform algorithm programs (FFT) and used it to have and calculated the values in terms of frequency, severity and stages and then take advantage of the results obtained for the work and compared with the results of generated biomedical signals FFT results.

That waves obtained from program (FFT MATLAB program) in words Lab values measured by the standard unit (dB), the use of a standard (dB) contributes to reduce the size of graphics and charts derived.

In which the results are :

- **Figures (8, 9)** show the FFT MATLAB program results for the ECG standard signal from the Biopac Student Lab PRO 3.7 device.
- **Figures (10,11)** show the FFT MATLAB program results for the EMG standard signal from the Biopac Student Lab PRO 3.7 device.

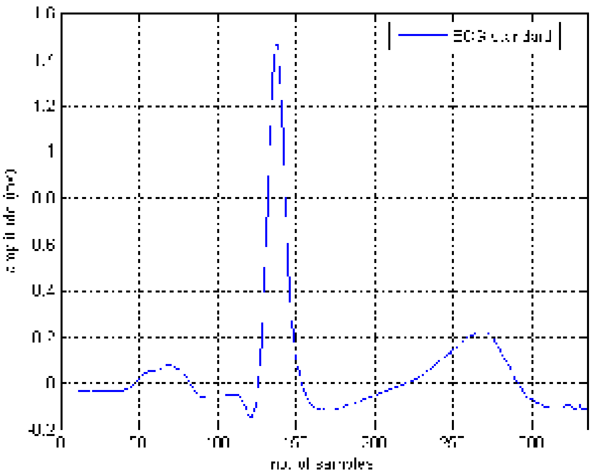

Fig. (8) Standard ECG MATLAB signal.

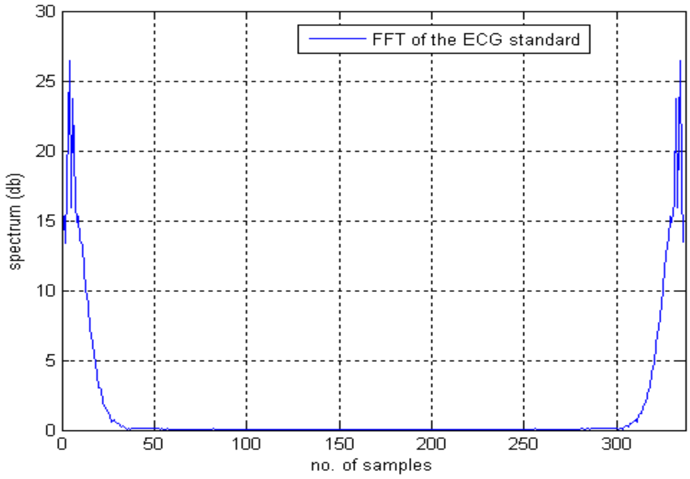

Fig. (9) The FFT MATLAB results of the Standard ECG signal.

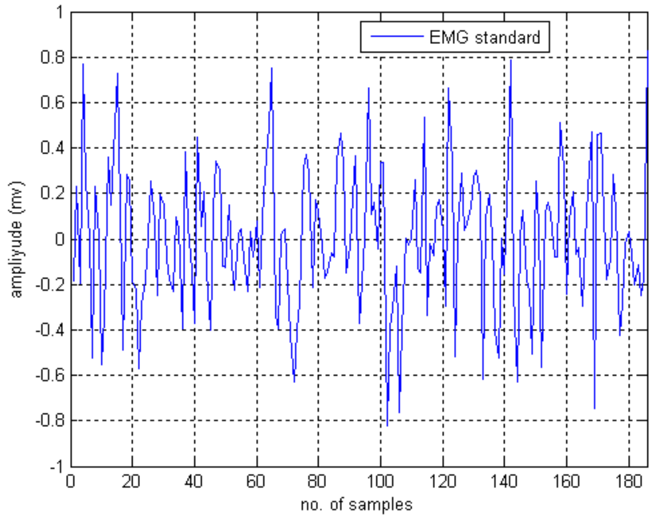

Fig. (10) The standard EMG MATLAB signal.

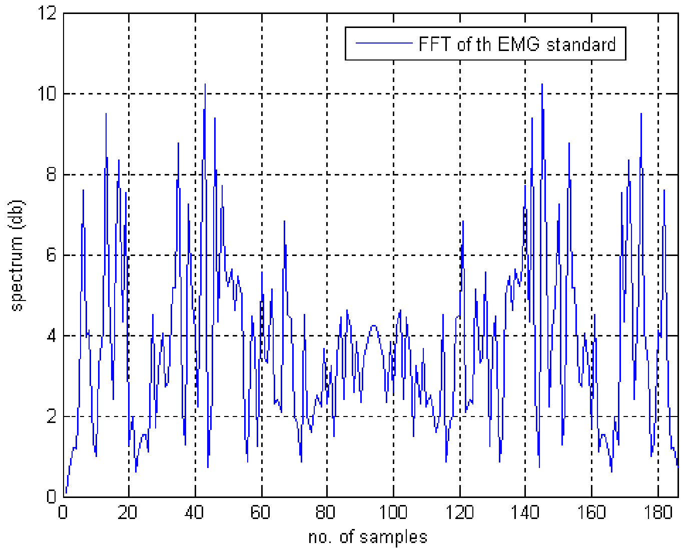

Fig. (11) The FFT MATLAB results of the Standard EMG signal.

4. THE RESULTS FROM BIO-SG DEVICE

After we connected the circuit of the BIO-SG that shown in **Figure (5)** and give appropriate orders to select the output desired biomedical signals (it is ECG signal or it is EMG signal) by pushing two push button one for selection the type of the output desired biomedical signals and the second push button for starting.
We was recorded the results and they are :

- The generated ECG output wave shown in **Figure (12),** this picture was taken from the output of the BIO-SG device on a digital oscilloscope, in which the picture showing the scales for voltage, time, frequency and power.

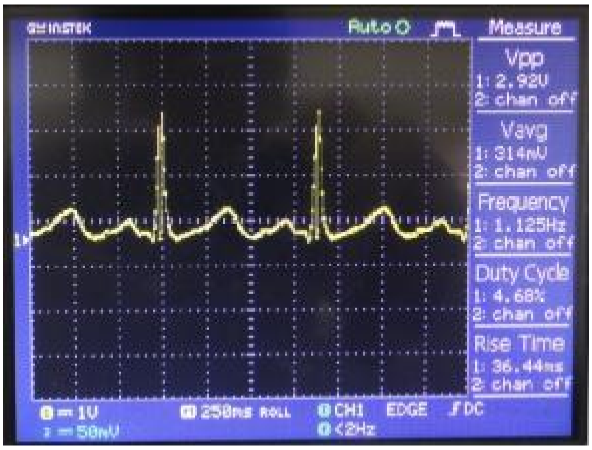

Figure (12) The generated ECG output wave.

- The generated EMG output wave shown in Figure (13), this picture was taken from the output of the BIO-SG device on a digital oscilloscope, in which the picture showing the scales for voltage, time, frequency and power.

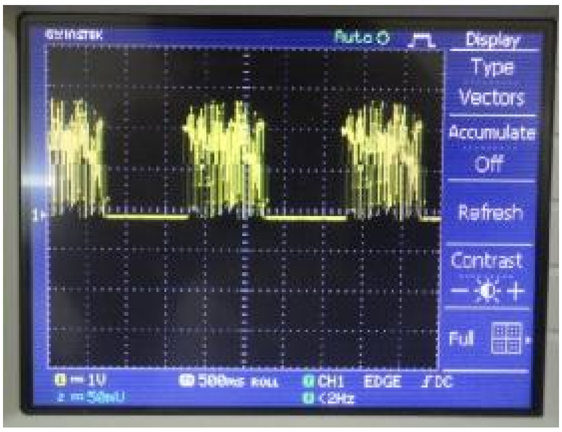

Fig. (13) The generated EMG output wave.

- Also, Harmonics Map were calculated for the biomedical waves generated from our system (BIO-SG) and by the same method of calculating the harmonics of the standard biomedical waves and by using the same FFT MATLAB program. So the results were as follows:

1) **Figure (14)** shows the ECG generated signal by the BIO-SG using the MATLAB program.

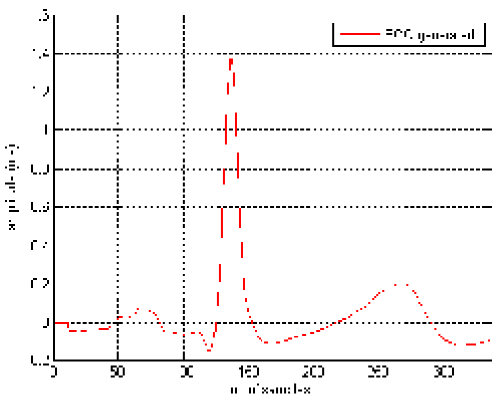

Fig.(14) The ECG generated signal by the BIO-SG using the MATLAB program.

2) **Figure (15)** shows the Harmonics Map for the ECG generated signal by the BIO-SG using the FFT MATLAB program.

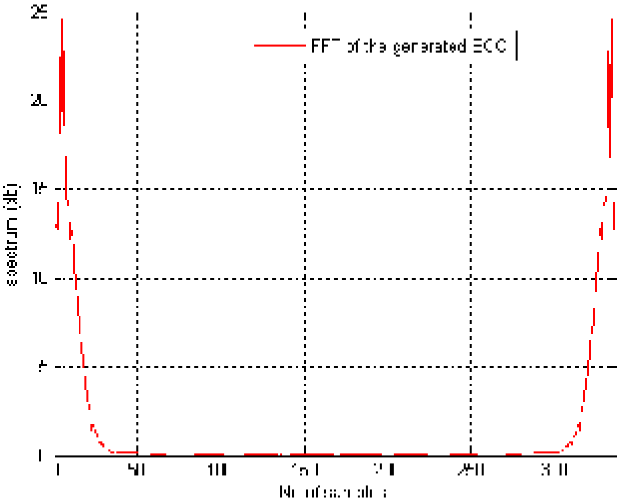

Fig. (15) The Harmonics Map for the ECG generated signal by the BIO-SG using the FFT MATLAB program.

3) **Figure (16)** shows the EMG generated signal by the BIO-SG using the MATLAB program.

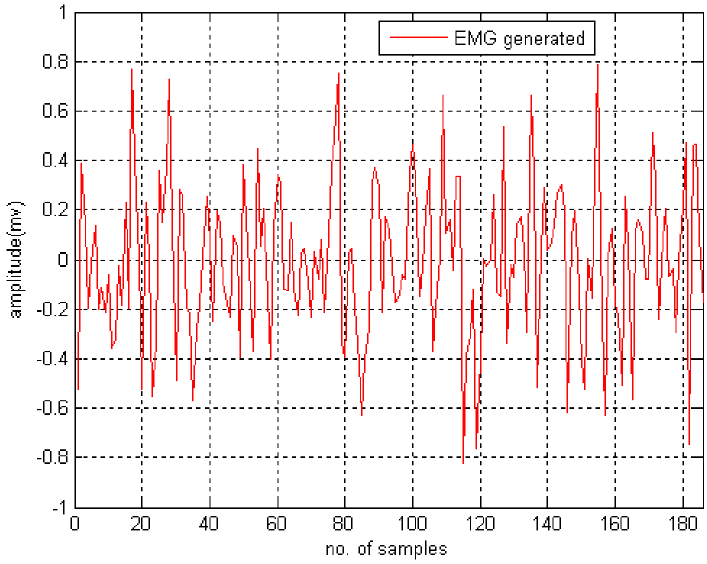

Fig. (16) The EMG generated signal by the BIO-SG using the MATLAB program.

4) **Figure (17)** shows the Harmonics Map for the EMG generated signal by the BIO-SG using the FFT MATLAB program.

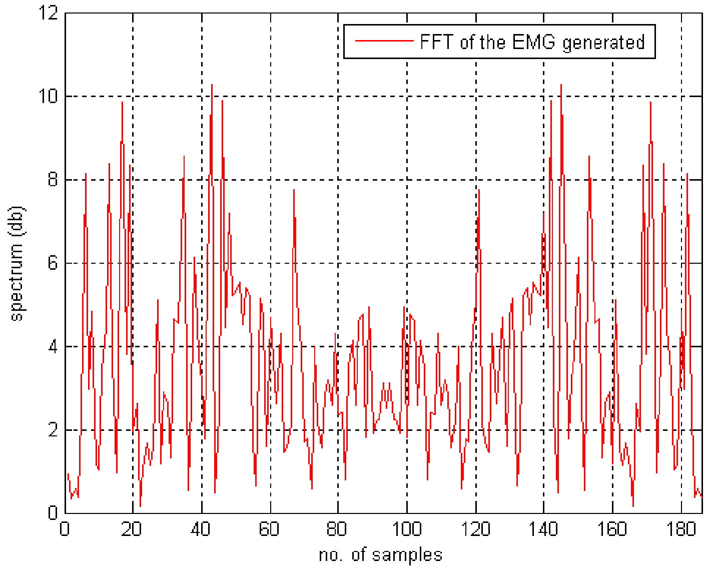

Fig. (17) The Harmonics Map for the EMG generated signal by the BIO-SG using the FFT MATLAB program.

5. CONCLUSION

From our paper we can conclude that:

1- It is possible to build and operate our BIO-SG in a simple way, easy way and it is less expensive than existing devices.
2- We have been able to achieve good credibility and reliability of our system, according to the results and rates of errors in the signals generated by our system.
3- Ease of use and plasticity for beneficiaries and users that could benefit from the device.
4- The small size of the device and low power consumption. The easy possibility of development and change, and we can adding any other biomedical signals to the BIO-SG device.

In order to find the error ratios we used th e equation (3) for computing the error ratios in the biomedical signals generated by our BIO-SG which were (the ECG and the EMG) and by using the computing MATLAB program we found the error ratios, were which :

1- The error ratio in the ECG generated signal comparing with the ECG standard signal was (0.2783 dB).
2- The error ratio in the EMG generated signal comparing with the EMG standard signal was (0.5906 dB).

From the error ratios results for the biomedical generated signal from the BIO-SG device, its clear that error results it were low ratios and matching the standard possible errors.

The error ratios made it possible for accrediting the BIO-SG device as a standard biomedical generator and can be used in the testing fields.

We had been selected the ECG and the EMG biomedical signals to the fact that our BIO-SG device was an experimental device and then it possible to adopt the addition of other biomedical signals (like EEG) or even possible to add references common diseases for the ECG and the EMG biomedical signals.

In addition the ECG and the EMG biomedical signals are somewhat regular signals as compared with other signals such as EEG signals in terms of its time value ,frequency and levels.

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