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Cost Effective, Portable Spasticity Quotient Determination System for Multiple Sclerosis

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ABSTRACT: Multiple sclerosis (MS) is a neuro-degenerative disease which affects approximately 2.5 million people in the world [1]. MS is an inflammatory demyelinating condition, i.e. it is caused by damage to myelin (a fatty material that insulates nerves, acting much like the covering of an electric wire).It (myelin) allows a nerve to transmit its impulses without any loss of data (action to be taken) and the source (target muscle). Hence, the demyelination causes spasticity in the muscles of the patient. Spasticity is hardening of muscles, i.e. the muscles of the affected patient lose their tenderness. Hence as the spasticity of the muscle increases, the impulses from the nerve cells get more and more delayed, hence in the end causing complete immobility.MS is, as of today, an incurable, deteriorating disease. In this paper we would like to present a method for the detection of the level of spasticity in the muscles caused by MS. This design is based on the fundamental principle of Electromyogram (EMG). In this report we have tried to develop a cost effective, home based method of determining the spasticity quotient.

KEYWORDS: Multiple Sclerosis, Electromyogram, Spasticity, AD8221.

I. INTRODUCTION

Multiple Sclerosis is a disease of the white matter tissue. This white matter consists of nerve fibres which are accountable for transmitting communication signals throughout the body. The affected people, develop patches of damaged lesions on the white matter of the central nervous system. There are several symptoms of MS like unusual sensations, bladder problems, trouble walking, dizziness and fatigue. The common relation between these symptoms is the increase in the inactivity of the muscles. This inactivity is quantified as spasticity. It is a very important term, with respect to the patients suffering from MS , as this factor helps in determining the course of the disease and hence the medication. Unfortunately, there isn't a user friendly device for calculation the spasticity quotient in a particular muscle, unlike the automatic blood glucose meters. The tests relating to spasticity can only be done in clinics, by the process of electromyogram. This process is costly and can be difficult for patients in the developing countries to undergo this process on regular intervals. We were able to discover this problem, and come with a solution by proposing a cost-effective, home based system for measuring the spasticity of muscles. This device can revolutionize the sector of home based medical devices.

Using the Trust-Worthy algorithm it defines a threshold value to the SUs to overcome the PUE attacks. It enables CR-Networks nodes to efficiently utilize the available spectrum channels. Nodes, which can easily find various licensed channel opportunities without interfering the primary system increases. This reveals that it has a potential to be able to convert the various network conditions into a performance improvement.

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II. ELECTROMYOGRAM

An electromyogram (EMG) measures the electrical activity of muscles at rest and during contraction. Nerve conduction studies measure how well and how fast the nerves can send electrical signals [2]. The brain sends electrical impulses to the rest of the body parts through the nerve cells and this impulse is measured by the EMG electrode. Basic working of an EMG electrode is to measure the change in the ionic current in a muscle under study, which happen due to the excitation produced by the nerve cells.

A. MECHANISM OF NERVE CONDUCTION WITH A BODY CELL

Every cell in human body has a cellular wall, which is semipermeable in nature. Of all the nutrients present around a human cell the most predominant ions are potassium (K+), sodium (Na+) and chloride (Cl-). These three ions play an important role in the cell excitation and hence in the muscle excitation (muscle reaction to the nerve impulses). Now the semipermeable cell membrane readily allows the exchange of potassium and chloride ions through it, whereas blocking the sodium ions (when in its steady or unexcited state). Hence the density of the K+ ions and the Cl- ions inside the cell is more than that of outside the cell. On the contrary the density of the Na+ ions is less or even negligible on the inside of the cell as compared to the outside. Presently, the potential of the cell is negative with respect to its surrounding and is known as the resting potential of the cell. Now when a nerve cell excites the targeted muscle cell, what this impulse basically does is to excite the cell membrane. Now this excited cell membrane becomes completely permeable and allows the passage of the Na+ ions. Hence due to the density difference there is a heavy inflow of the Na+ ions from the outside to the inside. This results in the generation of an ionic potential. Hence now the density of Na+ ions inside the cell and in the body liquid surrounding the cell, equalises. But still, the density of K+ ions is more inside the cell. Hence overall potential of the cell becomes positive with respect to its surrounds. This potential of the cell is known as the action potential. This potential always should have a positive value (for a normal human cell). For a person suffering from MS, the nerve cannot fully transform the impulses of an optimum electrical (ionic potential) level, so as to fully activate the cell membrane. As the disease progresses, the ability and hence the impulse strength decreases and leads to incoordination of the muscle. Here the cell activity as well as the muscle reaction after a nerve impulse excitation can be measured using an EMG machine. Hence this helps the affected person as well as the concerned doctor to trace the path of the disease. There are other ways of detecting the trace of the disease like MRI, PET-scan and many more, but they become a costly affair for an average person in a developing country.

B. EMG SPECIFICATION

A well-established EMG signal is stochastic (random) in nature. The amplitude of the signal can range from 0 to 10 mV (peak-to-peak). The usable energy of the signal is between 0 to 500Hz. The most dominant frequency band in this range is between 50-150Hz [3]. To sum it up, the EMG signal doesn't have a characteristic shape (unlike ECG) and hence looks like a random noise signal.

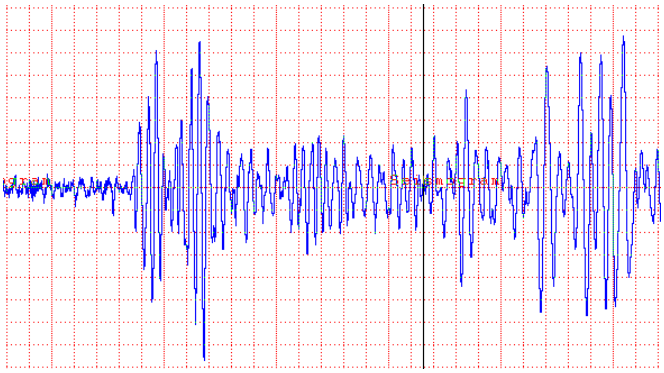

Figure (1): The above diagram depicts a typical EMG wave [10].

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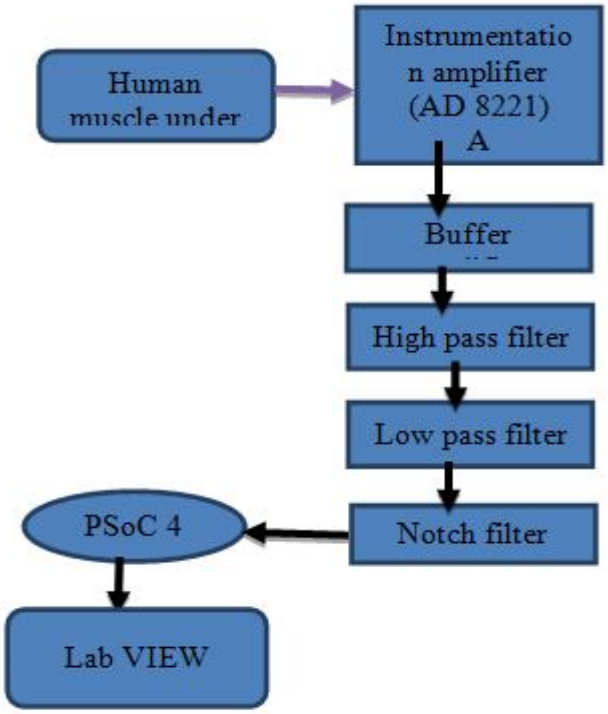
III. THE DESIGN

The design of this project consists of:-

- An instrumentation amplifier :- AD8221
- A quad J-FET OPAM :- TL084
- Disposable EMG led x 3
- PSoC 4 prototyping kit
- LabVIEW software

A. BLOCK DIAGRAM



B. INSTRUMENTATION AMPLIFIER

An **instrumentation** (or **instrumentational**) **amplifier** is a type of differential amplifier that has been outfitted with input buffer amplifiers, which eliminate the need for input impedance matchingand thus make the amplifier particularly suitable for use in measurement and test equipment [4].

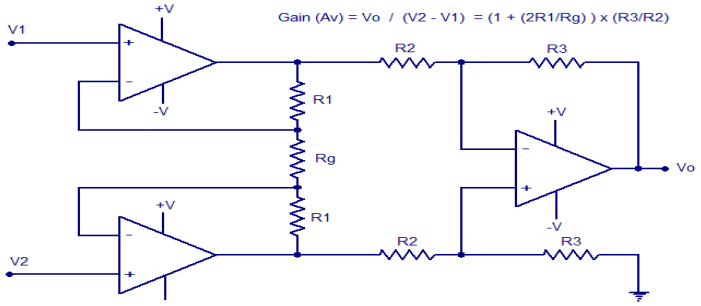


Figure (2): The figure above [5], is the basic design of an instrumentation amplifier.

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In the figure, the resistor Rg is a gain setting resistor. One of the most important parameters of the instrumentation amplifies is their high CMRR (common mode rejection ratio). The ability of a differential amplifier to not pass (reject) the portion of the signal common to both the + and – inputs [6]. Hence higher the CMRR, higher is the noise cancellation from the input terminals. Therefore, the instrumentation amplifier that we have implemented is AD8221. It is a precision instrumentation amplifier. The AD8221 is a gain programmable, high performance instrumentation amplifier that delivers the industry's highest CMRR over frequency in its class. The CMRR of instrumentation amplifiers on the market today falls off at 200 Hz. In contrast, the AD8221 maintains a minimum CMRR of 80 dB to 10 kHz for all grades at G = 1 [7].

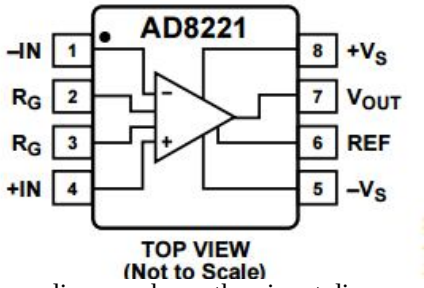

Figure [3]: The above diagram shows the pinout diagram of AD8221.

Hence, the 3 OPAMP design of the conventional instrumentation amplifier is now replaced by just one OPAMP with the gain adjustable pins.

C. QUAD-OPAMP

Quad-OPAMP is an OPAMP which internally contains four OPAMPs within itself. So what is the need of this chip? Well to answer in brief, it occupies less space, works on a single power supply connection (hence drawing less power, compared to using four different OPAMPs) and the most important point , less noise drift . The quad-OPAMP that we have used in our design is TL084. It's a chip by Texas Instruments.The TL08xx JFET-input operational amplifier family is designed to offer a wider selection than any previously developed operational amplifier family. Each of these JFET-input operational amplifiers incorporates well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit. The devices feature high slew rates, low input bias and offset currents, and low offset-voltage temperature coefficient [8]. In this project, we used a quad OPAMP to mount 4 different circuits, requiring four different OPAMPS, onto just one OPAMP. These four circuits are classifies as:

- **Buffer amplifier**
  It is just a simple non inverting voltage follower circuit with a gain of 10. It is basically used for impedance matching in the circuit as well as to add up to the overall gain of the system.

- **High Pass Filter**
  High pass filter used in this circuit is to remove the DC offset voltage and its cut-off frequency I kept as 0.1 Hz. This is helpful in eliminating the DC values which add up to the noise generated in the final signal.

- **Low Pass Filter**
  Here the low pass filter is designed to eliminate higher frequencies which do not contribute to the actual EMG signal. We have implemented a low pass filter with a cut-off of 200Hz. As mentioned earlier the actual information of an EMG signal is limited to 50-150Hz, this cut-off range is highly tailored to meet the needs of the device application.

- **Notch Filter**
  Notch filter is used to eliminate an extremely narrow band of frequencies. Ideally a notch filter eliminates a particular frequency, but in the practical electronics scenario, it is successful in eliminating extremely narrow band of frequencies. Here a notch filter is designed with a cut-off frequency of 50Hz. This frequency is chosen so as to eliminate the noise produced by the supply. The notch used in the circuit is an active notch so as to increase the efficiency of the filtering.

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D. DISPOSABLE EMG LED

This is basically a bio potential electrode which is best suited for single time use. It is one of the best electrodes available at extremely low cost and isn't messy to handle (unlike other bio potential electrodes, which require the application of conducting gel). Every use requires a set of three of these leds. A pair of electrode is used for differential bio potential measurement and the third led is used as ground. By differential bio potential electrode, we mean that the signals are gathered from two parts of the same muscle. Differential bio potential electrodes are also known as bipolar electrodes.

E. PSoC 4 PROTOTYPING KIT

PSoC stands for Programmable System on Chip and is a result of most of the fastest growing sector of electronic, VLSI. The reasons for the use of this particular microcontroller is:

- Highly cost effective: costs $4 per piece.
- Has a pair of 12-bit SAR-ADCs in built
- Has a CURRENT DAC built in
- Consumes and operates on less power:
- Small in size makes it a perfect fit for the design of the project.
- The IDE used for programming this microcontroller is extremely easy to understand.

Here we need a microcontroller to convert the final signal from the signal acquisition part to be digitally filtered and processed. Also this microcontroller is fundamental in sending the final processed signal to communicate with the PC.

Figure(4): PSoC 4 prototyping kit

F. LabVIEW

LabVIEW (short for Laboratory Virtual Instrument Engineering Workbench) is a system-design platform and development environment for a visual programming language from National Instruments [9]. This is by far the most advance tool for data acquisition, processing of the data and displaying it on the PC screen, for someone not familiar with the MATLAB coding style. This software tool was used by us to finally process the signal achieved by PSoC and present it in a numerical value (peak-to-peak voltage value) and also present a run-time graphical display unit. Hence helping the patient to understand the strength of his muscles over time. The program which we wrote, even logs the data and plots it over time, to give a fair idea about the deterioration of the muscle health and responsiveness over time.

IV. FUTURE SCOPE

In the future we would like to make this project a sellable device for home use. And also we plan to implement it in clinics so as to reduce the cost of these tests. We are also working on developing an Android Application which will take the signals directly from the PSoC , via a Bluetooth module and mail the test signals to the corresponding doctor. Hence making it easy for the doctors as well as the physiotherapists to plan the medication and the exercise pattern (respectively).

V. CONCLUSION

MS is an incurable disease and hence nothing much can be done with the medications. Whereas physiotherapy plays a very important role in delaying the adverse effects of this disease. Hence with our project we plan to help the affected patients detect the declination in the muscle health being at home and inform their doctors and physiotherapists

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