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SMART ELECTRICAL MUSCLE STIMULATOR USING RASPBERRY PI4

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Abstract

This research built a Smart Electrical Muscle Stimulator (EMS) by using Raspberry Pi4, OLIMEX 328, and an EMG shield. The idea of this research is to follow the ECG and EMG of the patient while his muscle stimulation is carried on, the stimulation level will be decided according to the ECG output. Using Raspberry Pi4 gives the possibility of Bluetooth remote control and programable parameters of the EMS device.

Keywords: EMS, Raspberry Pi4, OLIMEX 328, EMG shield, BrainBay.

1. Introduction:

A smart electrical muscle stimulator is a device that uses electrical impulses to stimulate muscles in the body, which can be used for therapeutic purposes or as a way to enhance muscle performance. In combination with a Raspberry Pi 4 and OLIMEX 328 with an ECG and EMG shield this device can be made even smarter and more versatile.

The Raspberry Pi 4 is a powerful single-board computer that can be used for a wide range of applications. It has built-in Bluetooth and Wi-Fi connectivity, as well as a number of ports for connecting various peripherals. With the right programming and software, it can be used to control a variety of devices, including an electrical muscle stimulator.

The previous researches describe the features of EMS signals, (Azman) [1] shows in utilizing the EMS, the frequency, pulse width, ramp time, duty cycle and amplitude are among the vital parameters of EMS, Frequency refers to the pulses produced per second during stimulation and in the units of Hertz. Most clinical regiments use a frequency between 20 to 50Hz to obtain optimum results, although, it also differs accordingly to the intervention, intention, or objectives at that time. Higher frequencies have proven to be more comfortable because the force response is smoothed and only gives out a tingling effect, whereas,

lower frequencies give out a tapping effect that distinguished the individual pulses.

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The use of electrical stimulation with the exercises followed by the trainer contributes effectively to the development of muscle strength, and the use of modern technology in measurement and development effectively contributes to
the economy with the effort and time expended by the coach and the player in developing achievement (Abdulrahman) [2].
While (AL-IBRAHEEMI, et al) [3], proved that when weightlifting players are affected with muscle impairments it is suggested to apply Electrical Simulators to revive them from the skeletal muscle impairment. The solution can be given by EMS not only for the muscles but also for the affected bones.
The research by (Ahmad and Hasbullah) [4], proved that the Variations of training programs may give an opportunity for EMS training to show greater results.
To refer to muscular atrophies, (Achata, et al) [5] explain that atrophy refers to the decrease in the size of an organ due to the loss of protoplasmic mass, it is necessary to specify that, unlike hypoplasia, where the organ does not develop or there is arrested development, atrophy is the reduction of the organ that reached its normal development. In order to reduce muscle fatigue, FES is triggered only when the muscle is not strong enough to make a movement. In this situation, resulting vibrations are detected using an inertial measurement unit coupled with feature extraction and a neural classifier (Marzetti, et al) [6].

2. Design of EMS system:

There are two main types: Transcutaneous Electrical Nerve Stimulation (TENS) and Neuromuscular Electrical Stimulation (NMES). TENS stimulates the nerves that transmit pain signals to the brain, while NMES stimulates the muscles directly.
This research worked with Neuromuscular Electrical Stimulation. The components of the smart EMS devices and module are shown in fig. (1).

Fig. (1) Smart EMS devices and module.

The appropriate electrodes are connected to the OLIMEX 328 microcontroller. The microcontroller will generate the electrical signals that will be applied to the electrodes. The microcontroller generates the desired waveform and frequency for the electrical stimulation. An Arduino IDE is used to program to create the code for the microcontroller. The microcontroller connected to the Raspberry Pi4 using serial communication. The Raspberry Pi4 sends commands to the microcontroller to start and stop the stimulation or change the stimulation parameters, A user interface was developed for the Raspberry Pi4 to control the electrical stimulation. BrainBay software [7], is used to create a graphical user interface (GUI) that allows the user to adjust the stimulation parameters as shown in fig. (2).

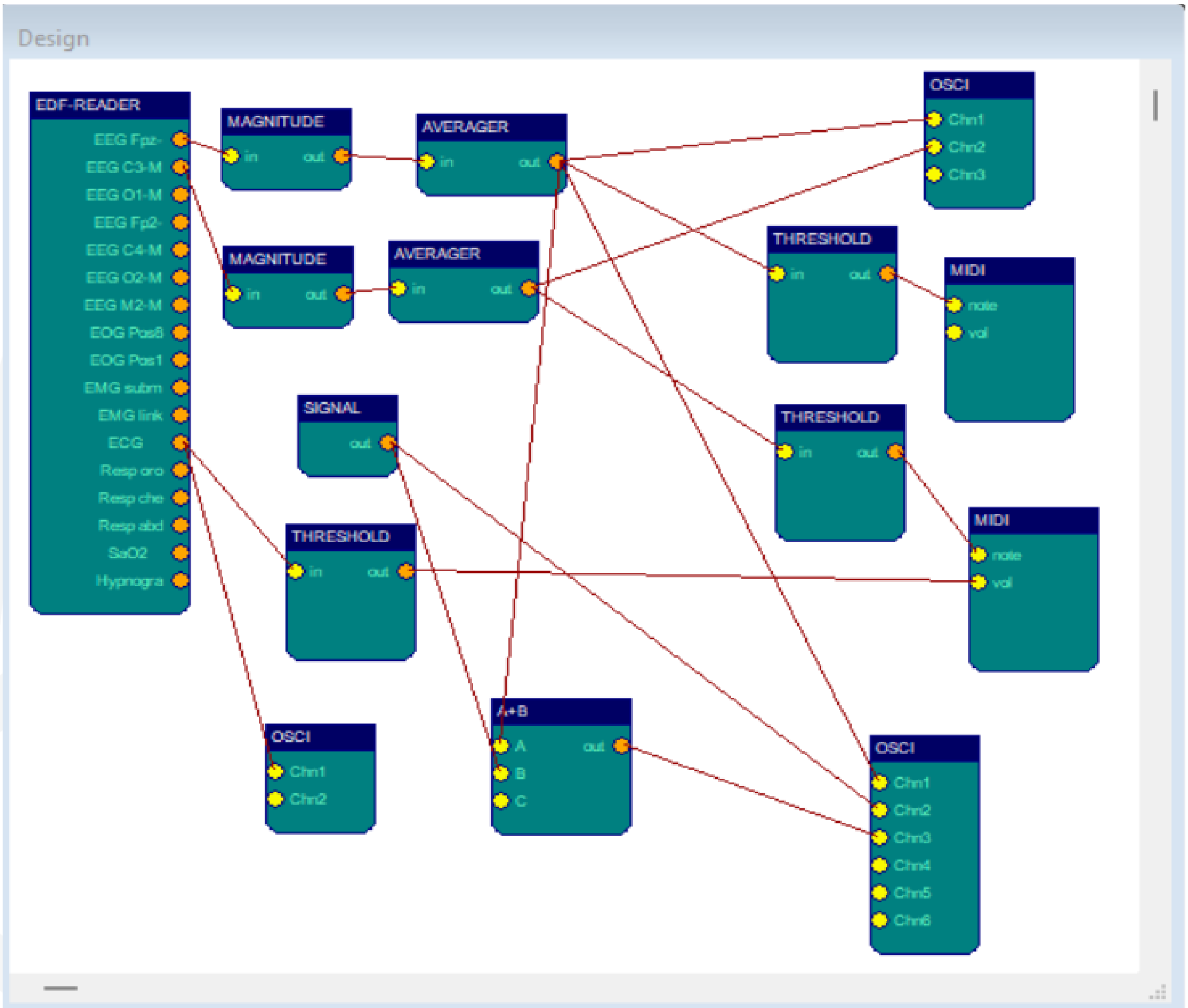

fig. (2) BrainBay Design for Smart EMS.

3. Results and Discussion

This research designed an EMS course for the biceps muscle of a man, the course increasing the frequency and amplitude of the stimulating signal gradually, the signal is a square wave with a frequency of (10-30) hertz and a voltage from (0-50) volts with a very low current does not exceed 2 mA to avoid electric shock. The procedure is monitored by the level of the ECG signal, which will control the parameters of the stimulating signal, fig. (3) shows the first step of the stimulating procedure.

Fig. (3) Smart EMS signals.

The stimulation signal voltages that must be applied to the muscles using the smart EMS digital therapy machine depend on the mode and intensity of the therapy being performed.

The maximum stimulation voltage depends on the mode and intensity selected. The device typically delivers a series of short pulses of electrical stimulation, with each pulse lasting a few milliseconds, and the pulse frequency and width are also adjustable by the Raspberry Pi4.

The monitoring of the EMG graph, while the stimulation is processed, can provide valuable information about the effects of the stimulation on the muscles, including the strength and timing of muscle contractions and the potential for muscle fatigue or damage. It can be used by therapists and medical professionals to optimize therapy parameters and ensure safe and effective treatment.

EMG can sometimes affect ECG readings because the electrical signals produced by muscles can interfere with the electrical signals produced by the heart. This interference can make it difficult to accurately read the ECG and can lead to false readings, if a patient is moving during an ECG, the electrical signals produced by their muscles may create noise in the ECG signal, making it difficult to distinguish the heart's electrical activity from the muscle activity. Similarly, if a patient has muscle tension or spasm in the chest area during an ECG, this can also interfere with the ECG reading, to avoid EMG interference during an ECG, it is important to ensure that the patient is as relaxed as possible and not moving during the stimulation. The use of conductive gel or paste on the skin can also help to reduce muscle interference and improve the accuracy of the ECG reading.

4. Conclusion:

This research built and test a smart Electrical Muscle Stimulation (EMS) system using Raspberry Pi4, OLIMEX 328 microcontroller, and EMG & ECG shield.

According to this system, the stimulation procedure can be programmable and highly adapted to the patient’s condition.

A general User Interface (GUI) was designed for this research using BrainBay software for control and monitoring purposes.

The frequency and the width of the stimulation signals can be controlled by the Raspberry Pi4 automatically according to the designed thresholds of the EMG and ECG graph of the patient or by the trainer using GUI to avoid any muscle overload or tissue damage, or any required modification or correction for the stimulation procedure.

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