Design and Implementation of a Programmable Electrical Muscle Stimulator (PEMS)

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Abstract

“This research designed and constructed a Programmable Electrical Muscle Stimulator (PEMS) using an OLIMEX 328 microcontroller, an EMG shield, and controlled by a Raspberry Pi 4. The basic concept of this research is to measure the ECG and EMG of a patient while muscle stimulation is carried out. The parameters of stimulation pulses will be determined according to the ECG output. Using the Raspberry Pi 4 allows for Bluetooth remote control and programmable parameters of the PEMS device.”

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

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1. Introduction:

A programmable electrical muscle stimulator, in this research, is a device that uses electrical pulses to stimulate certain muscles in the body, which can be applied for treatment or as a way to improve muscle performance. With the combination of a Raspberry Pi 4 and OLIMEX 328 with an ECG and EMG shield, this device can be made even more programmable and efficient. The Raspberry Pi 4 is a powerful single-board computer that can be used for a wide range of biomedical signal processing applications. It has Wi-Fi connectivity, built-in Bluetooth, as well as several ports to communicate with various peripherals. With the right programming and software, it can be used to control a variety of devices, including an electrical muscle stimulator. Previous works of literature describe the features of EMS signals; (Azman) [1] shows that utilizing the EMS, frequency, pulse width, ramp time, duty cycle, and amplitude are among the main parameters of EMS. Frequency refers to the pulses produced per second during stimulation and is measured in Hertz. Most clinical treatments use a frequency range between 20 to 50Hz to obtain optimum results; it also varies according 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 distinguishes the individual pulses."

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 achieving success (Abdulrahman) [2].

Meanwhile, (AL-IBRAHEEMI, et al) [3] show that when weightlifting players are affected by muscle weakness, it is suggested to use Electrical Stimulators to treat them for skeletal muscle impairment. EMS can provide a solution not only for the muscles but also for the affected bones.

The research by (Ahmad and Hasbullah) [4] has proven that different training programs may yield greater results when combined with EMS training.

(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. To reduce muscle fatigue, FES is triggered only when the muscle is not strong enough to move. 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:

Transcutaneous Electrical Nerve Stimulation (TENS) and Neuromuscular Electrical Stimulation (NMES) are the two main types of EMS. 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 PEMS system are the Ri4 microcontroller, OLIMEX 328 (Arduino-like board) with (EMG, ECG) shields, as shown in Fig. (1)."

Fig. (1) PEMS devices and module.

The basic aim of the PEMS constructed in this research is to generate stimulation pulses with a desired amplitude and frequency using suitable electrodes connected to the OLIMEX 328 and EMG-ECG shields, with overall control done by the Ri4.

A C-Arduino program is written using an IDE to generate proper code for generating the desired stimulation pulses. The parameters of the stimulation pulses (amplitude, frequency, and duration) are calculated by the Ri4 single-board computer. These parameters are calculated by comparing the ECG signals with EMG signals of the person under test. Then, the parameters are sent to the OLIMEX 328 to generate the stimulation pulses, which are attached to the selected muscle by EMG electrodes.

BrainBay software [7] is used to create a Graphical User Interface (GUI) to interact with the PEMS system. The design of the GUI is shown in Fig. (2)."

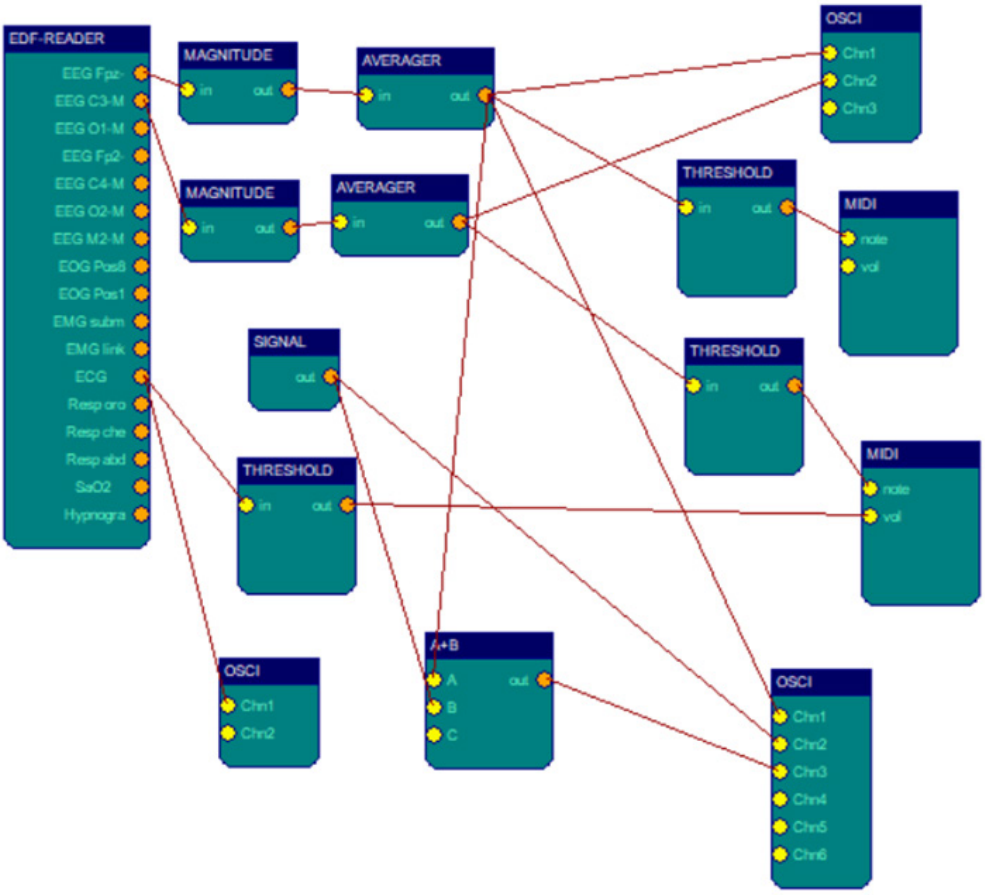

Fig. (2) BrainBay Design for Smart EMS.

3. Results and discussion:

This research designed a training course that stimulates the biceps muscles of a male under test. The frequency of these pulses varies from 10 to 30 Hz, while the amplitude ranges from 0 to 50 V, with a current not exceeding 2 mA to avoid electrical shock. During the stimulation procedure, the ECG signals of the person under test were monitored and compared with threshold values. According to the results of the comparison, the parameters of the stimulating pulses were calculated. Fig. (3) shows the first step of the stimulating procedure."

Fig. (3) PEMS signals.

The stimulation signal voltages that must be applied to the muscles using the PEMS digital therapy machine depend on the mode and intensity of the therapy being performed. The maximum voltage amplitude of the stimulation pulses depends on the mode and intensity selected for the stimulation course. 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 Pi 4.

The PEMG graph can be monitored during the stimulation process, providing 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 supervisors and medical professionals to optimize therapy parameters and ensure safe and effective treatment.

It is important to take into consideration that the ECG-measured signals can be affected by EMG signals, as they may interfere with the ECG signals, especially if the patient moves during the stimulation process. Accurate and efficient software filtering processes were followed in this research to overcome this problem."

Conclusion:

This research built and tested a programmable Electrical Muscle Stimulation (PEMS) system using Raspberry Pi 4, 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 width of the stimulation signals can be controlled by the Raspberry Pi 4 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, tissue damage, or any required modification or correction for the stimulation procedure.

4. References:

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