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Design and Development of Portable Transcutaneous Electrical Nerve Stimulation Device and Basic Principles for the use of TENS

Ajinkya Sonwane
Dept. Instrumentation and Control Engineering
College of Engineering Pune
411005
Email:sonwanead16.instru@coep.ac.in

Dr.C.Y.Patil
Dept. Instrumentation and Control Engineering
College of Engineering Pune
411005
Email:cyp.instru@coep.ac.in

Gaurav Deshmukh
Dept. Instrumentation and Control Engineering
College of Engineering Pune
411005
Email:deshmukhgr16.instru@coep.ac.in

***Abstract*— Nowadays current generators are used to control the delivery of electrical currents across the surface of skin to stimulate the nerves, this techniques used is known as Transcutaneous Electrical Nerve Stimulation (TENS). In this paper we are going to propose a TENS system which can be used to relieve any patient's muscular pain and sprain using electrical current. We attempt to generate two basic modes in TENS device which are conventional and burst patterns. The ADC and PWM functions in PIC18f4550 microcontroller have controlled the duty cycle of output. Specifically we describe the two main techniques in detail and further describe the fundamental principles for the use of TENS depending on each technique. Platform also focuses on increasing safety of the user.**

Keywords—pain; electrical current; TENS; Conventional TENS; AL-TENS; microcontroller; electrode;

I. INTRODUCTION

It is intuitive to use local stimulation like stroke, massage or rubbing of painful parts of the body or external stimulation like ultrasound, iontophoresis, heat, moist heat, cold, laser, acupuncture, vibration as a means of stimulating the skin for the relief of painful conditions. Electrical current are known to stimulate the nerve tissues. One of the technique used to stimulate nerves is Transcutaneous Electrical Nerve Stimulation (TENS). This technique uses electrical currents to stimulate the nerves close to the surface of the body by delivering electrical currents across the intact surface of the skin (transcutaneous). Electrical current is delivered through the skin using conducting pads.

The idea of electrical stimulation for pain relief is not a new one. Ancient Greek records report that an electric fish could produce numbness.

The Canadian Physiotherapy Society's definition for TENS is "The use of electrical currents to produce analgesia or hypoalgesia [1]."

Principle of TENS is based on Melzack and Wall's gate control theory of pain. Melzack and Wall proposed that the transmission of noxious (pain-related) information by small diameter nerve fibres in the nervous system could be reduced if there was simultaneous activity in larger diameter nerve fibres that normally transmit non-painful touch related information [2].

II. TENS TECHNIQUES

The International Association of Pain (IASP) core curriculum defines TENS according to two main techniques [3]

A. Conventional TENS (continuous mode)

1. High frequency (50–100 Hz), low intensity (paresthesia, not painful), small pulse width (50–200 μs).
2. Electrode localization: cover the painful region
3. Duration: about 30 minutes.

In conventional TENS changes in amplitude, frequency and duration can be easily felt, so it is preferred when using TENS for the first time. Output of the conventional TENS is monophasic or biphasic rectangular waveform. Fary and Briffa found more adverse skin reactions occurred using monophasic waveforms, and concluded that monophasic electrical stimulation should be used with caution [4].

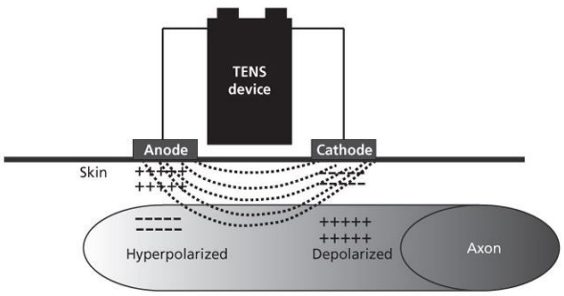

Fig 1. A build-up of negative charge beneath the cathode creates a membrane potential that depolarizes the axon [1].

The electrical resistance of the skin and underlying tissues to the current delivered by the stimulator is an important factor that may influence the efficiency of the stimulus. This resistance varies with conditions such as skin temperature, peripheral circulation, size of the electrodes and the sort of conductive gel used.

B. Acupuncture-like TENS(burst mode)

1. Low frequency (2–4 Hz), higher intensity (to tolerance threshold), longer pulse width (100–400 μs)
2. Electrode localization: usually at traditional Chinese acupuncture points, or trigger points, but one can also use it at the painful region.
3. Duration: about 30 minutes

When burst patterns are used to induce phasic muscle contractions the internal pulse frequency should be set above the fusion frequency of skeletal muscle (i.e. between 20pps and 50pps).

III. Fundamental Principles For The Use of TENS

A careful physical diagnosis of the patient is necessary before application of TENS. TENS doesn't cure the disease or abnormality underlying the pain. From the different modes available with TENS units, conventional TENS high frequency (50-100Hz) low intensity (parasthesia, not painful) small pulse width (50-100μs) is always the first mode to be tried, as it is easier to administer the technique and patient taking opioids are more likely to respond to conventional TENS. If no pain relief is obtained after 20-30 minutes of stimulation, electrode sites should be changed. If stimulation is ineffective after the evaluation of various electrode sites, AL-TENS should be tried.

There are various outlooks whether dosing regimens must be prescriptive or open, and how often and for how long individuals should administer the TENS unit. For conventional TENS maximum pain relief occurs in the presence of a strong, non-painful TENS sensation so an open dosing regimen where individuals keep the TENS device switched on whenever the pain is present is likely to be optimal. Individuals should take regular, short breaks from stimulation by turning TENS unit off for 10-15 minutes every 1-2 hours, although electrodes can remain in situ. Skin condition beneath the electrodes should be monitored as minor skin irritation may occur, and skin should be washed when electrodes are eventually removed. It is wise to apply electrodes to adjacent fresh skin on a regular basis. For AL-TENS, which is stronger form of stimulation, muscle fatigue and delayed onset muscle soreness are of concern, especially if stimulation is prolonged and generating contractions of large muscle mass, so dosing regimens of 20-40 minutes a few times a day is advised.

IV. Proposed System Work

In this system user has to select the mode from available modes which are continuous or burst mode. Frequency, amplitude and width in continuous mode can be adjusted using analog input to ADC of PIC18F4550. Under the patient's control the current is gradually increased until tingling is felt. The frequency of burst pattern are usually permanent. The whole system will be powered by 9V battery.

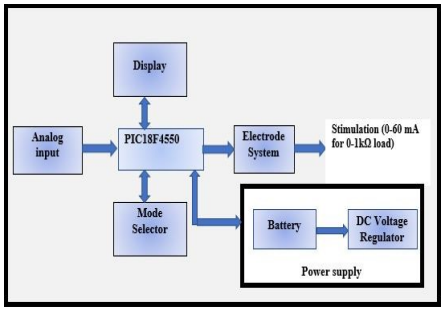

Fig 2. TENS device

A. Microcontroller

Fig.3 shows a PIC18F4550 microcontroller from microchip used in this project. It is 40 pin microcontroller with 32K flash program memory, 256 bytes of EEPROM, 35 I/O ports, 13 channels of 10-bit ADC.

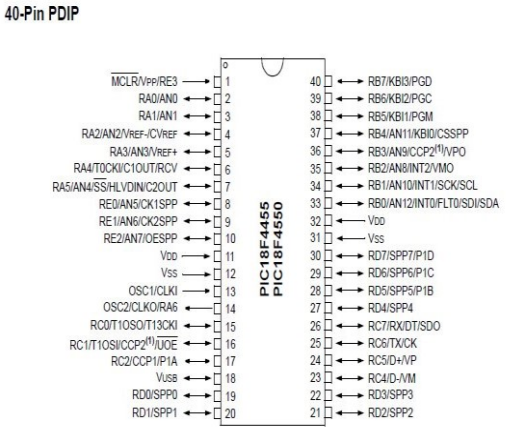

Fig. 3. Microchip PIC18F4550 microcontroller pin diagram [9].

B. Battery

A power source to generate electrical currents is a 9V PP3 battery. Battery usage increases with the use of longer pulse durations, higher pulse amplitudes, higher frequencies and continuous pattern of pulses which is to be delivered

C. Analog input

Potentiometers are used to control Frequency, duty cycle and intensity of current that is to be delivered through electrodes.

D. Mode selector

A button to select the mode between continuous and burst mode.

E. Electrode system

Lead wires are used to take the currents from the TENS device to electrode pads which are attached to desired skin location. Electrode pads used were 50mm*50mm in dimension.

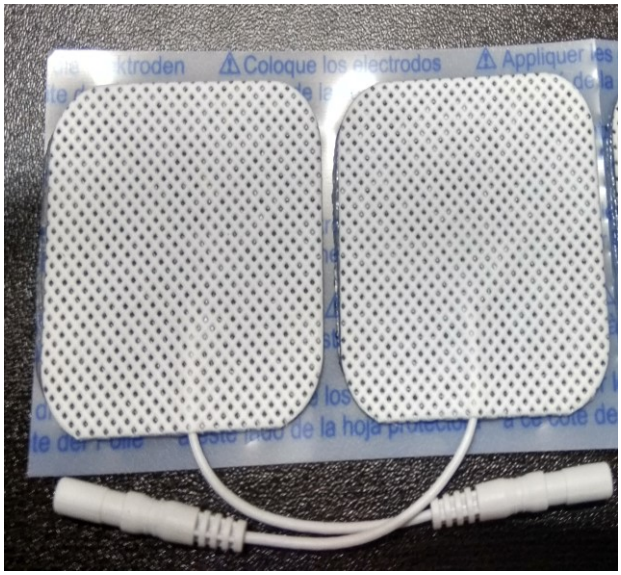

Fig. 4. Electrode pads

V. Results and Discussions

In this device we are expecting the generation of continuous and burst waveforms using ADC, PWM and Timer functions in PIC18F4550 microcontroller. Symmetric waveforms with variable frequency (50-100Hz) were generated using Timer0 module of PIC18F4550.

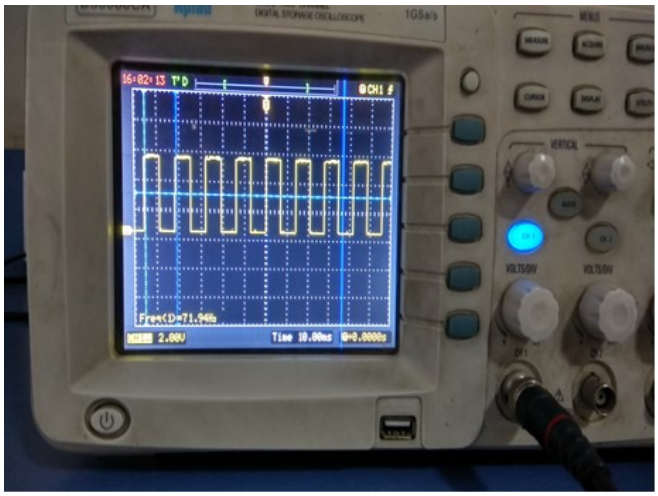

Fig. 5. Symmetric square wave generated for Continuous mode of TENS with 71.94 Hz frequency.

VI. Conclusion

Research suggests that use of TENS is safe and side effects are less. Sometimes patient feels pain radiating around its source. In such cases, spotting the original source of pain and placing electrodes at precise location is crucial in alleviating pain of patient. Development of microcontroller based system makes it portable and cost effective. TENS treatment is relatively inexpensive when compared with long term drug therapy.

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