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Mobile Phone based Transcutaneous Electrical Nerve Stimulation

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ABSTRACT

Transcutaneous electrical nerve stimulation (TENS) is a drug-free non-invasive pain relief method which uses electrical impulses to stimulate the nerve endings at or near the site of pain; thinning the pain and bequeath with a tingling or massage like sensation. This paper deals with a novel method of developing a mobile phone based TENS to make the treatment personal, less cost and more versatile. The waveform is loaded onto a memory card of the mobile phone. The waveforms are then loaded by the Android based TENS App to provide treatment to site of pain. The conductive gel is applied to the site of pain and TENS electrodes are placed on top or next to the painful area where the signal is applied.

Keywords

Android, Electrodes, Mobile phone, Lab VIEW, Analgesia.

1. INTRODUCTION

Transcutaneous electrical nerve stimulation (TENS) deals with application of electrical stimulus to nerves in Human body as a means of pain therapy. [14] TENS increases pressure and heat pain thresholds in the healthy people and reduces the mechanical and heat hyperalgesia in arthritic animals. [16]

Local vasodilatation of blood vessels in ischemic tissues theory (Leandri *et al.*, 1986) states that Trigger points develop in muscle when there is a loss of local blood flow (ischemia) due to an acute insult or scar tissue remaining from an earlier injury. They are involved in muscle pain, muscular rheumatism, muscular inflammation, and inflammation of the fibrous tissue. [13]

Gate control theory (Melzack and Wall, 1985) states that when an electrical current is applied to a painful area, transmission of pain (via small diameter C & A-delta fibers)

to the brain is inhibited by the large diameter, fast-conducting A-beta fibers. (See Figure 1) As Central Nervous System (CNS) can interpret and transmit only one form of sensory stimulus at a time, the brain does not perceive pain. [13] This uses frequencies of above 10pps (pulses per second or Hz) but usually between 80-100pps. [17]

Stimulation of acupuncture point causes sensory analgesic effect(Melzack, 1988) states that Acupuncture is based on energy lines (meridian) and entry points (acupuncture points) and the stimulation of these points using TENS causes a sensory analgesia effect by inhibiting or changing the pain evoked nerve impulses at several levels in the nervous system. [13]

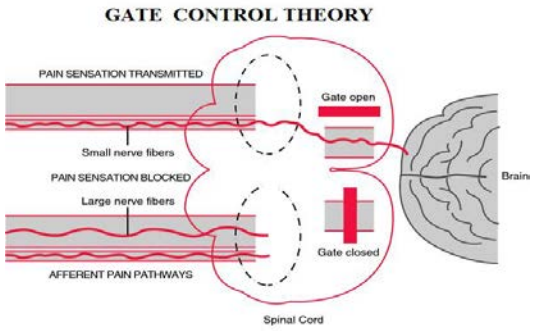

Fig1. Gate Control Theory (Representation of Pain transmission to brain)

Opiate-mediated control theory states that the brain can secrete its own pain killer (Endorphins) which are neuropeptides capable of acting on the CNS and peripheral nervous system to reduce pain. [13]

Low frequency TENS (also called as Acupuncture like TENS) uses frequencies of 2 - 4 HZ, which encourages the body to produce endorphins and increases local blood flow both of which relieve pain. [17] High frequency TENS (80-100 Hz) acts very quickly giving a pleasant tingling sensation and blocks the pain impulses going to the brain (Gate Control theory). [17]

Faradic treatment is given to produce muscle contraction and deals with treatment of muscle weakness. Plain faradic is described by train of faradic pulses of same amplitude. Surged faradic includes series of surges of pulses with gradual increase in amplitude.

Table.1. Review of Effectiveness of TENS in pain treatment [7]

Condition	Existing Reviews	Study Done by
Acute Pain	7/14	Reeve, Menon and Corabian (1996)
Chronic Pain	9/20	Reeve, Menon and Corabian (1996)
Post-Operative Pain	2/17	Carroll *et al.* (1997a)
Labour Pain	3/8	Carroll *et al.* (1997a)

The TENS device available in the market makes use of the 555 timer as a multivibrator to generate the required frequency and pulse which is given to waveform modifier circuits such as exponential waveform circuit to generate necessary waveform for the treatment. The Microcontroller based TENS machines use microcontroller to generate the waveforms in a digital manner.

2. BLOCK DIAGRAM

The User generates waveform describing the amplitude, phase, frequency, and pulse width for the purpose of treatment as each users have different body conditions, pain level and site of body. After generation of the waveform file, it is loaded into the SD card of the mobile phone.

The waveform from the SD card (see Figure 4) is loaded into the Android App and played. After application of the gel to the site of pain, the electrodes are placed. The gel is used to allow current to enter into the body and prevents heating of the tissue. The electrodes are attached to the site of pain either with aid of pads or disposable electrodes are used.

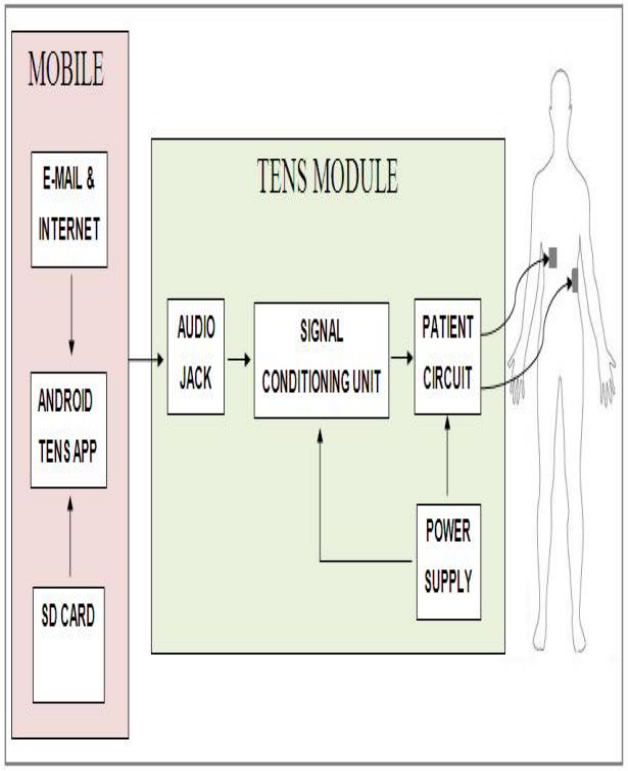

Fig.2 Block Diagram of Mobile Phone based Transcutaneous Electrical Nerve Stimulation

3.2 Signal Conditioning Unit

The output from the audio jack of the mobile is of very low amplitude so it has to be amplified to a range of about 0-100mA. The required amplification is done using an

3. CONSTRUCTION

3.1 Generation of TENS waveform using LabVIEW

TENS waveform is generated using LabVIEW with option to modify its parameters such as amplitude, phase, duty cycle and offset. The frequency is set around 0-200 Hz. The generated waveform is displayed in the user interactive front panel. (see Figure 3) The user is provided with an option to E-Mail the audio file from the LabVIEW program using SMTP (Simple Mail Transfer Protocol).

Large diameter nerve fibres (Aβ & Aα) are having low activation threshold to electrical stimuli comparing to small diameter nerves (Aδ & C). [13] Large diameter afferents, small diameter afferents and motor efferent are excited by low-intensity, high frequency (10–250 p.p.s.) with pulse durations of 10-1000 μs. [13]The cathode that excites the axon is placed proximal to the anode to prevent the blockade of nerve transmission due to hyperpolarisation. [8]

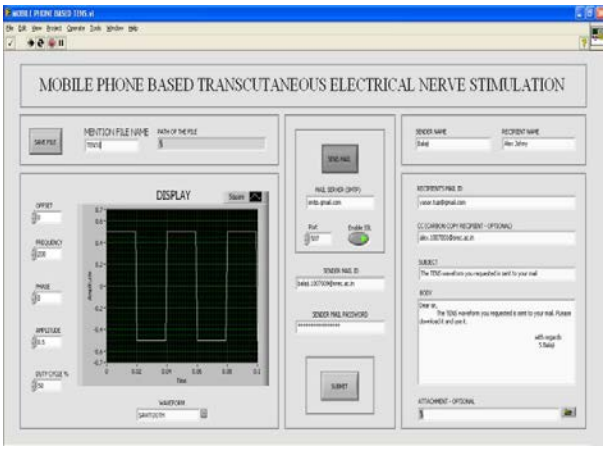

Fig.3.The User interactive front panel to generate TENS waveform

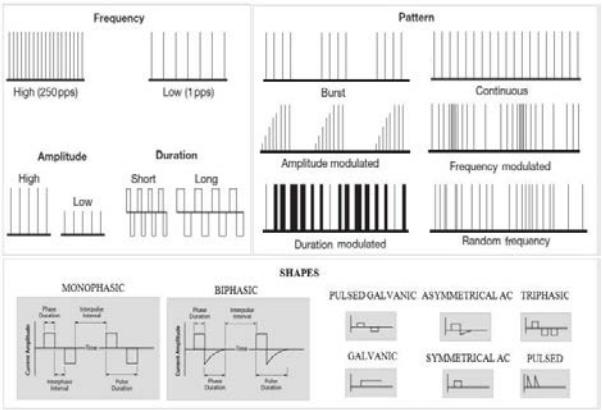

Fig.4 Waveforms used in Transcutaneous Electrical Nerve Stimulation [8], [15]

instrumentation amplifier (AD620). The power output from AD620 is not enough to cause necessary stimulation of human tissue so the signal is power amplified using 7W power amplifier.

3.3 Patient Circuit

The output from the signal conditioning unit is given to ferrite core transformer of 1:10 primary to secondary coil ratio is used to increase the current at the output stage. Ferrites are dense, homogenous ceramic materials made by combining iron oxides with oxides or carbonates of metals such as manganese, nickel, zinc or magnesium. Ferrite core transformers are preferred due to their small size, high magnetic permeability, electrical isolation, high power handling capability and wide bandwidth of operation. Electromagnetic interference is suppressed by usage of the ferrite core.

3.4 Electrode Placement

Electrodes are always applied to healthy innervated skin. In case of skin lesion or amputation or altered skin sensitivity, electrodes are placed over the main nerve trunk which arises from the site of pain. In case of conditions such as phantom limb pain or trigeminal neuralgia, electrodes are placed at a sites contra-lateral to area of pain.

Electrodes can also be placed over the spinal segment of spinal cord associated with the site of pain. There are four broad categories of anatomical site to which TENS electrodes can be applied - painful area, peripheral nerve, spinal nerve roots and other specific points (acupuncture, trigger and motor points). [15] Electrodes can be placed over dermatomes, myotomes or sclerotomes associated with site of pain. Peripheral nerves which pass via painful area are stimulated by placing electrodes at the site where they become superficial.

Table.2.Analgesic Effects of TENS [10], [11], [12]

Acute Pain	Chronic pain
• Post-operative pain • Labour pain • Dysmenorrhoea • Musculoskeletal pain • Bone fractures • Dental procedures	• Low back • Arthritis • Stump and Phantom • Post-therapeutic neuralgia • Trigeminal neuralgia • Causalgia • Peripheral nerve injuries • Angina pectoris • Facial pain

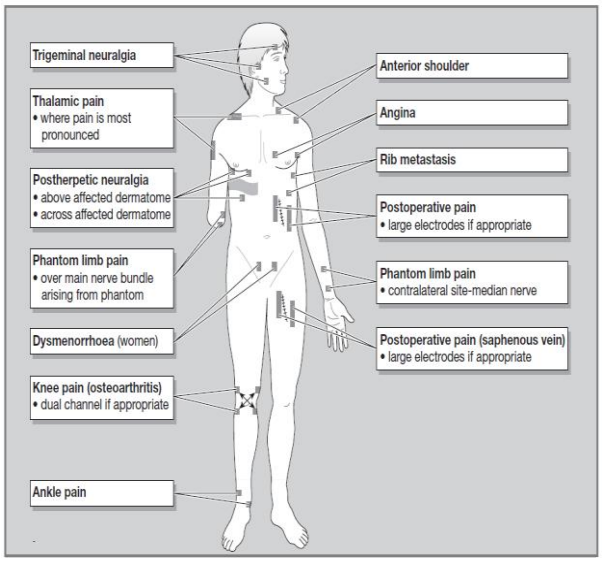

Fig.5. Placement of Electrodes for common pain conditions- Anterior View [8]

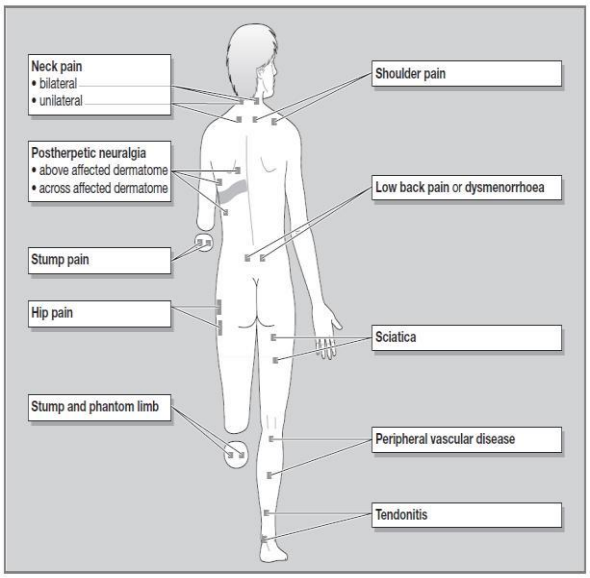

Fig.6. Placement of Electrodes for common pain conditions- Posterior View [8]

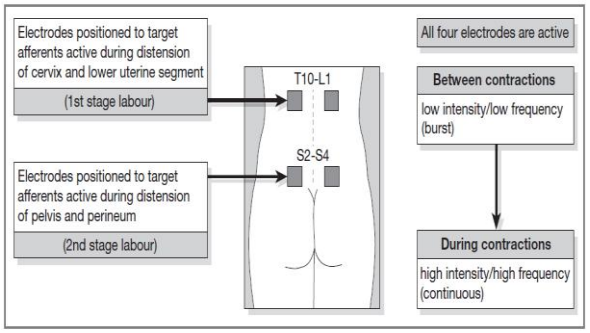

Fig.7. Electrode placement for treating Labor pain [8]

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Table.3. Comparison between Mobile phone based TENS and TENS available in market [7]

Parameters	TENS available in market			Mobile Phone based TENS
Unit	Rehabilicare /ProMax	BioMedical Life Systems /BioMed 2000	ProMed Specialties /ProM 100	
Digital/Analog	Digital	Analog	Analog	Digital
Pulse Width, µs	50 - 400	50 - 250	40 - 250	As Required
Channels	2	2	2	2
Waveform	Asymmetric rectangular biphasic with zero net dc	Asymmetric rectangular biphasic	Asymmetric biphasic square with zero net current dc	As Required
Output current, (mA)	0 - 100	0 – 80	0 - 80	0-70mA
Output Frequency(Hz)	2 - 160	2 - 150	2 - 150	As Required

The electrodes have backing material made of non-woven cloth or tan tricot or foam type and mostly water resistant in nature. The electrode connection type is snap button type with female connector of 0.08.

Self-adhesive and carbon electrodes are the two most common types of electrode. The latter can used applied using a wet gel or hydrogel pad, either with or without the use of tape. Self-adhesive electrodes are now widely available in a broad range of shapes and sizes, which makes it easier to apply TENS for a variety of pain conditions. The main factors that determine the type of electrode used include allergic reaction, cost, ease of use and availability. [15]

Large-sized electrodes are used to treat pain covering large area. Acupuncture like TENS (ACU-TENS) is used to provide generalized pain therapy. Similar sized electrodes are placed in a trial and error method to find the appropriate site for treatment. Ohm meter point locator is used to find areas of low skin resistance for electrode placement.

4. RESULTS AND ANALYSIS

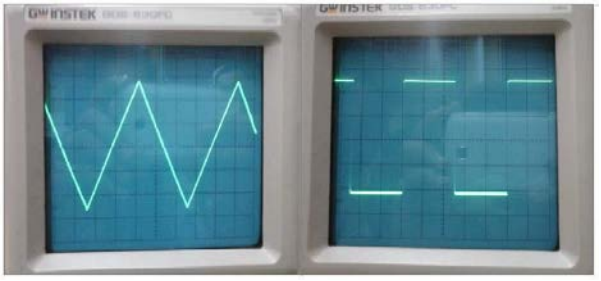

Fig.8. Waveform output from the Mobile phone based TENS

The output waveform (see Figure 8) from Mobile phone based TENS is displayed in a CRO (Cathode Ray Oscilloscope). The waveform output from the entire module remained similar to the wave being generated and played in mobile. An output power of around 5 watts is achieved. The process of loading the waveform into our TENS module is very less time consuming compared to the models available in the market. The waveform files can be simply sent via Bluetooth or can be transferred via E-Mail. There is no limitation in case of number of pre-programs in our module as it consumes very less space in the SD card.

The pulse width, frequency, treatment mode and shape of waveform are designed by the user in the LabVIEW based module thus breaking the barriers in the TENS available in the market. Our TENS module can achieve the concept of patient specific waveform for pain therapy i.e., for each of the patient waveform of different shape, frequency, pulse width, intensity can be designed and given via different modes of treatment, thus increasing the quality of treatment.

5. CONCLUSION

The presentation of this paper deals with design of a versatile, low-cost mobile phone based Transcutaneous Electrical Nerve Stimulation device capable of treating chronic and acute pain. The Mechanism of treatment, associated waveforms, electrode placement and analgesic effects of TENS was discussed. The comparison is made between the designed TENS and TENS available in the market. (see Table 3)

This device would act as a means of treatment for above mentioned pain. The Project can further be enhanced by designing a feedback electrode which would prevent chances of shock to the patient.

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