

Smart Transcutaneous Electric Nerve Stimulation Device

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Abstract- Many People in our daily life are suffering from diabetic neuropathy, acute and chronic pains, or sports injuries which need special care and medication. However only medication or Physical Techniques won't give relief or fast recovery so some methods such as Transcutaneous Electrical Nerve Stimulation (TENS) are used by physiotherapists to help in relieving the pain and promote healing. Even used to reduce stretch marks and extract the pattern of human stimulus which helps in various studies. TENS is a process where the electrical signal is penetrated into the body and help relieve pain it's not only about physical pains recently TENS device called Cefaly was approved by the United States Food and Drug Administration (FDA) for the prevention of migraines and even TENS in some cases effective for relieving labor pain. The Smart Transcutaneous Electrical Nerve Stimulation device stands apart in providing patterned stimulation, preprogrammed frequencies, and supports various complex simulation patterns. Here this device provides interaction with users and machines which helps to extract human stimulus data which helps to study various patterns and implement diverse Machine Learning and Artificial Intelligence techniques. All types of electric nerve impulses are produced by this device and can be adjusted to a specific frequency that works for each individual's pain tolerance levels.

This device support both Bluetooth and Wi-Fi. Right now, it has been implemented using Wi-Fi to control TENS which is better and faster than Bluetooth and makes it cost-effective. The Smart TENS device is connected to a local network and interacted via a web browser makes it user-friendly.

Keywords—TENS, electrical signal, Smart TENS Device, ESP32, IRF520, Electro Pads, LiPo Battery, LiPo BMS.

I. INTRODUCTION

Transcutaneous Electric Nerve Stimulation is a simple, non-invasive process where electrical signals are penetrated into the body which helps to relieve pain. TENS helps to reduce pain caused by an extensive variety of situations including acute and chronic pains, sports injuries, labor pains, and other neuropathy problems. Generally, this sort of process is mostly used in health care settings by physiotherapists, nurses, and doctors. This makes it expensive and sluggish.

Hence to overcome these shortcomings a Smart TENS Device can be used. This device penetrates electrical signals at the place of injury which relieves pain. This device provides a level of symptomatic pain relief by exciting sensory nerves, thereby stimulating either the pain gate mechanism or the opioid system. Depending upon the intensity and frequency of the electrical signal the TENS Device activates different pain relief mechanisms in the body. One of the pain relief ways is by means of the pain

gate mechanism which involves activation of the A beta ($A\beta$) sensory fibers that reduces the dispatch of the noxious stimulus from the 'c' fibers, through the spine. The $A\beta$ fibers are going to be stimulated at a relatively high frequency. The second way is to simulate the A-delta ($A\delta$) fibers which respond preferentially at a much lower frequency, which will activate the opioid mechanisms and provide pain relief by producing endorphins (chemicals produced by the body to relieve stress and pain) in the spinal cord and brainstem and also increases the blood flow at the place of injury to relieve pain.

In the Smart TENS Device, there are three different modes of frequency and intensity which show different types of effects on various injuries. These modes can be controlled by a web page via a web browser using a smartphone, PC, or laptop with a local Wi-Fi network which makes it a convenient and user-friendly device.

This device also helps in extracting human stimulus data which helps in analyzing various patterns and performs multiple Machine Learning and AI techniques.

II. COMPONENTS

Smart TENS Device has the following components: -

A. ESP32

Figure 1 shows an ESP32 is a MUC with integrated Wi-Fi and Bluetooth connectivity. It is an ultra-low power consumption device and has a robust design. It has a high-level integration of power amplifier, low-noise receive amplifier, filters, and power management modules.

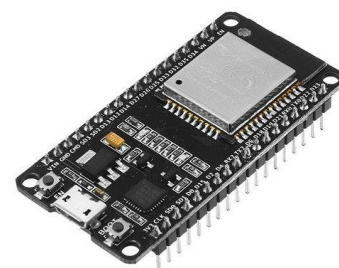


Figure 1

B. XL6009 Module

Figure 2 shows an XL6009 module which is a DC to DC BUCK-BOOST converter module that operates at a switching frequency of 400kHz. In such high frequency, it comes up with smaller-sized filter components compared with low frequency switching regulators. It is an efficient

switching regulator and the output efficiency is also significantly higher up to 94%. It has an input voltage of 3-32 volts and an output voltage of 5-35volts which is variable at the desired value.



Figure 2

C. IRF520 MOSFET

The IRF520 MOSFET is a Power Mosfet with collector current of 9.2A and has a breakdown voltage of 100V. The mosfet has a low gate threshold voltage of 4V. It has an output voltage of 0-24V. The IRF520 MOSFET is as shown in figure 3.



Figure 3

D. Electrode Pads

Figure 4 shows the Electrode Pads are made with the very best quality adhesive gel for max reusability. Carbon-fiber construction provides excellent conductivity and adaptability. They are often used easily for 30-40 times of use (each time you stick it on the skin and take away it, it's counted together time).



Figure 4

E. LiPo Battery

Lipo Battery is also known as Lithium Polymer batteries are rechargeable, thin, light, and powerful. 3.7V 1000mAH LiPo

Battery is used. These batteries provide higher specific energy than other lithium battery types and are used in applications where weight is a critical feature. LiPo Battery is shown in Figure 5.

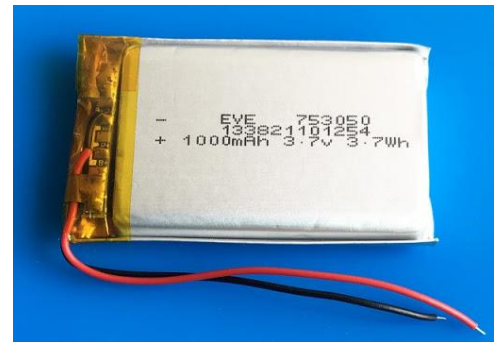


Figure 5

F. LiPo BMS

LiPo BMS is a Battery Charging Module show in Figure 6. TP4056 Li-Ion BMS is employed within the device it helps in charging the LiPo Battery. The TP4056 is a low-cost Lithium-Ion battery charger controller IC. It supports a constant current and constant voltage charging mechanism. Can Charge Current Up to 1000mA and also has current protection.



Figure 6

III. SMART TENS DEVICE

A. The block diagram of Smart TENS Device is shown in the figure 6.

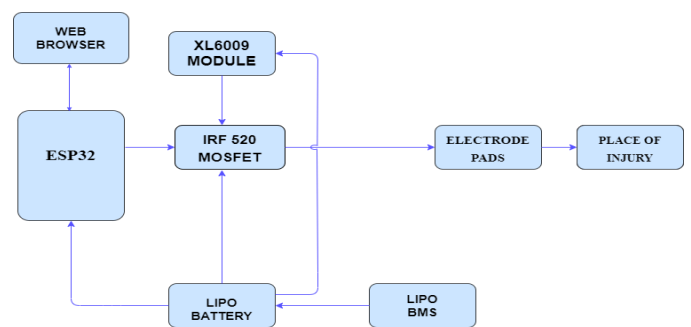


Figure 6

Brief Description of the Block Diagram:

- Power Supply for the device is provided by the LiPo Battery and the LiPo Battery Management System (BMS) is used the recharge the battery.

- Web Browser from any smartphone or PC runs the web page which is linked to the ESP32 Module through a local Wi-Fi network. This helps the user to select the required mode of frequency and intensity and also helps in collecting the human stimulus data and stores it in the server for future use.
- The ESP32 an integrated Wi-Fi & Bluetooth Module linked with the web page is used to generate square wave electrical signals at a specified frequency and intensity as per user-specified.
- The XL6009 Module works as a DC to DC BUCK-BOOST converter which boosts the intensity of electrical signals and fed to the IRF520 MOSFET.
- IRF520 MOSFET Circuit which has a high switching frequency with the help of ESP32 switching signals can give rise to electrical signals of the desired frequency with the intensity produced by XL6009 Module.
- Electrode pads have both positive and negative electrodes which are placed on the injury. These electrode pads penetrate the electrical signals into the body for pain relief and to cure the injury.

B. Working

Smart TENS Device works in three different modes which are controlled using the web interface. They are 1. Conventional TENS

2. Acupuncture TENS

3. Intense TENS

1. Conventional TENS: In this mode the frequency of the electrical signal is high and the intensity is low. Used at the site of pain this produces a strong and comfortable sensation and the duration of this mode is about 30min. It helps in activating large-diameter non-noxious afferent to generate segmental analgesia (loss of sensation of pain).

2. Acupuncture TENS: In this mode the frequency of the electrical signal is low and the intensity is high. Used over muscle or acupuncture points to produce a strong and comfortable contraction of muscles and the duration of this mode is not more than 20min. It helps in producing muscle twitch and to activate small diameter motor afferent to generate additional segmental analgesia.

3. Intense TENS: In this mode both the frequency and the intensity of the electrical signal is high. Used to produce extreme paresthesia and the duration of this mode is not more than 5min. It helps in activating small diameter noxious afferent to evoke peripheral nerve blockade and to generate additional segmental analgesia.

C. Applications

- Smart TENS devices are used as a non-invasive nerve stimulation system designed to reduce both acute, chronic pain sports injuries, labor pains, and other neuropathy problems by the application of electrical signals through electrodes placed on the skin for pain control.
- The site of application of electrodes of Smart TENS device is typically near the site of injury. It is possible

that application outside the site may also be effective, as central mechanisms can be activated by TENS.

- A Smart TENS Device can be personally controlled by the user through a web page. The settings can be adjusted, without the need of a medical professional. Generally, this device can be used for 15-20minutes per session, several times per day. Smart TENS Device can also be used to reduce pain from muscular trauma, joints, and nerve algesia, musculoskeletal pain. Unlike a lot of medication, there are virtually no side effects of this device.
- The use of this device might also reduce the number of painkilling medicines people usually take, for pain relief which further involves many side effects. As this device usually have no side effects.
- This device also helps in analyzing the human stimulus data and extracts it for the usage of both Machine Learning (ML) and Artificial Intelligence (AI) techniques. For example, now a day's robots and machines are controlled by human electrical impulses. The strength of these electrical impulses differs from person to person, so by using this device we can exactly find the strength of the electrical impulse of a person and can process ML and AI techniques perfectly.

IV. RESULT

As there are three types of modes in this device, we get three different output square waveforms with the predefined frequency and intensity of each mode. Smart TENS Device is as shown in figure 7

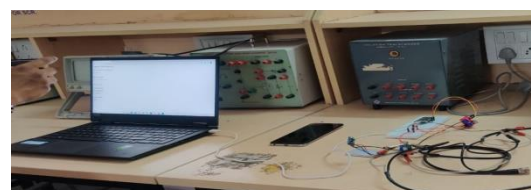


Figure 7

The waveforms of each mode are shown below:

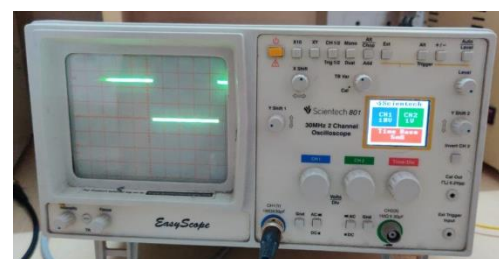


Figure 8: Conventional TENS Mode

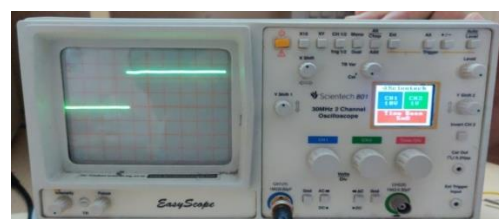


Figure 9: Acupuncture TENS Mode

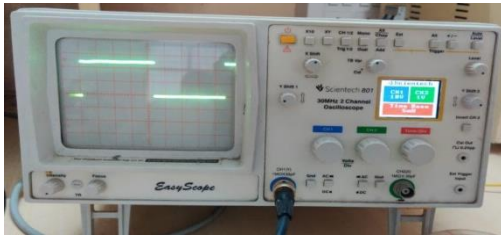


Figure 10: Intense TENS Mode

V. CONCLUSION

Research suggests that the use of this Smart TENS Device is safe and the side effects are less. Sometimes the patient feels pain radiating around its source. In such cases, spotting the original source of pain and placing electrode pads at the precise location is decisive in alleviating the pain of the patient. The development of ESP32 Module based system makes it portable, user-friendly, and majorly cost-effective. Usage of the Smart TENS Device relatively economical, safe, easy and also helps in extracting human stimulus data for ML and AI applications for example in robotics and records the user usage data for future reference.

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