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BUSER Transcutaneous Electric Nerve Stimulator Device Design

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Abstract

The Transcutaneous Electrical Nerve Stimulator (TENS) is one of the medical devices that uses electricity to stimulate the nerve and produce analgesic effects. A TENS device is a small battery-powered or city-powered device with ends attached to sticky pads called electrodes. TENS, with its main purpose of helping to reduce pain and muscle spasms, has a wide usage area, especially in arthritis, fibromyalgia, chronic pelvic pain, knee pain, menstrual pain, low back pain, sports injuries, and atrophic muscle tissue cases. In this study, a Transcutaneous electrical stimulation device, which is one of the physical therapy methods performed by applying electrical energy, was designed. Designed device; it is easy to use, low cost, and suitable for patients, and ardunio is used for integration and programming.

Keywords:

TENS device, gate-control theory, oscilloscope, pertinax, breadboard

Article history:

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Introduction

Transcutaneous electrical nerve stimulation (TENS) is a non-invasive, safe, easy-to-apply, portable, and inexpensive technique that provides pulsed electrical stimulation that can be varied in frequency, current intensity, and duration. The concept of TENS has historically been the subject of heated debate in scientific circles in terms of effectiveness. However, although this method of

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pain management has proven itself in clinical trials, there is disagreement to date about which pain syndromes and conditions TENS is appropriate for (Teoli & Ann, 2022). It has the advantage of allowing patients to control their pain autonomously through two or more skin electrodes to stimulate subcutaneous nerves for pain control (Pal et al., 2020). As a non-invasive analgesic therapy, transcutaneous electrical nerve stimulation is widely used to relieve pain in various clinical applications by delivering current pulses to the skin area to activate peripheral nerve fibers (Mokhtari et al., 2020). In the TENS device, the pads are attached directly to the skin. When the machine is turned on, small electrical pulses are delivered to the affected area of the body, which is felt as a tingling sensation. Electrical impulses can reduce pain signals to the spinal cord and brain, which can help relieve pain and relax muscles. These signals are first transmitted to the nerves located under the skin and from there to the brain via nerves. The sense of pain reaching the brain itself is replaced by electrical currents and thus the pain becomes undetectable. In fact, the pains continue in the body and the pain harms the body. The TENS device is only a method that prevents the perception of this pain to the brain. They can also stimulate the production of endorphins, which are the body's natural pain relievers (Johnson & Jones, 2017). TENS is used clinically by various healthcare professionals for the reduction of pain. The clinical effectiveness of TENS is controversial, with some studies supporting it while others rejecting its clinical use (Sluka & Walsh, 2003). Compared to many drugs, the device does not pose a risk of overdose. TENS units are generally highly adjustable, allowing the user to control pulse width, intensity and frequency. The low frequency of < 10 Hz in conjunction with the high intensity is used to generate muscle contractions. High frequencies > 50 Hz are used at low intensity to induce paresthesia without muscle contractions (Teoli & Ann, 2022).

This study, it is aimed to design the Transcutaneous electrical stimulation (TENS) device, which is the most useful form of electrotherapy technique commonly used in physical therapy methods, with a 2-mode and single-channel output system, unlike the ones on the market, and which applies low-voltage electric current.

Materials and Methods

Circuit Information

The circuit diagram shown in Figure 1 was taken as a reference and the materials were selected and the circuit diagram was drawn with the Proteus 8.1 Professional program. It was transferred to Ares 8.1 Professional environment after open circuit drawing. As indicated in Figure 2, the lines drawn between the circuit elements were selected in the T60-T80 range, the lines were placed more prominently in the printed circuit and they were designed in such a way that they would not come into contact with each other by adding a terminal block. In order to create the printed circuit, the drawings were transferred to Ares via Proteus and the paths in the printed circuit were made ready.

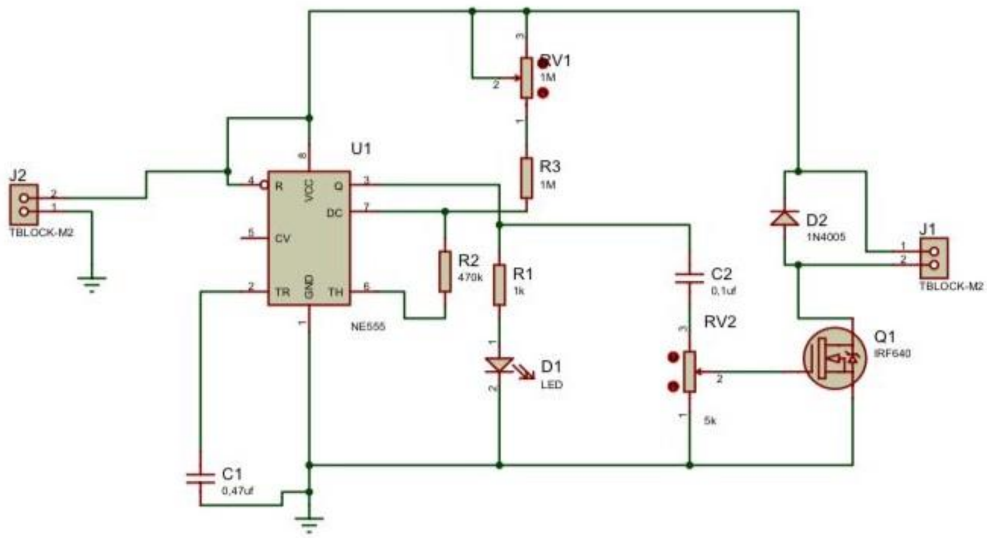

Figure 1. Open circuit diagram of the transcutaneous electrical stimulation (TENS) device

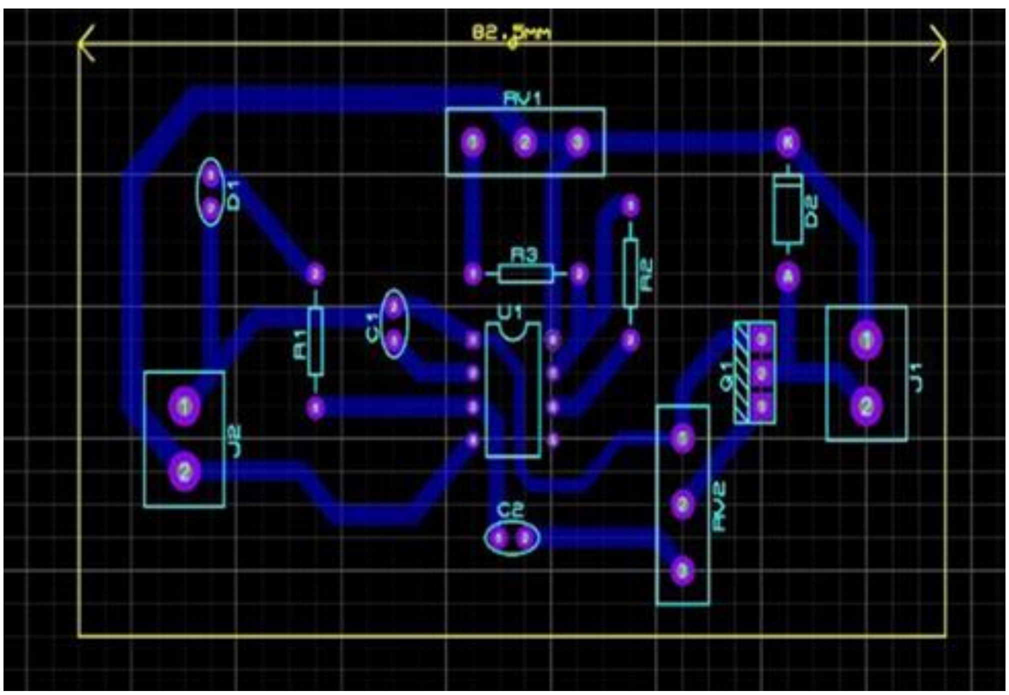

Figure 2. Printed circuit drawing

Print Circuit Stages

The printed circuit drawing in Figure 2 was printed on transfer paper by trying several dimensions. Printed using a laser printer as printer to transfer the toner with heat. Before the heat treatment, the plate was sanded and cleaned, and it was aimed to transfer the toner onto the pertinax without any problems. In order to transfer the circuit diagram on the transfer paper to the pertinax, the surface of the print was transferred to the plate by contacting the surface with heat for an average of 5 minutes, as shown in Figure 3. This step should be followed carefully and the iron should be moved to different points of the paper and at different angles, as deterioration may occur in the paths that are tried to be transferred in case of excessive heat exposure.

Figure 3. Passing the circuit to the pertinax with the help of heat

When the transfer paper heats up, the toner is transferred onto the plate. After this stage, the paper and pertinax are exposed to water in Figure 4 in order not to damage the roads, so that the sticking parts get wet and the transfer paper is removed more easily and without damaging the roads. By cleaning the circuit with the help of sandpaper, scratches were obtained on the copper.

Figure 4. Separation of transfer paper over pertinax

Figure 5. Melting of copper plate in solution

In the continuation of this application, the pertinax plate with the circuit lines removed is thrown into the solution prepared with 1/3 salt spirit and Hydrogen Peroxide in the mixing bowl in Figure 5, and it melts the copper in an average of 15 seconds, causing color change and steam output in the liquid. In order not to inhale the steam, it should be carried out in the open area or by wearing a mask, skin and clothing contact should be avoided. At the end of 15 seconds, the paths on the pertinax become clear. However, one of the points to be considered is that in case some of the roads do not come out completely, they should be thrown back into the solution and the lines should be clarified by careful follow-up. If it is kept in the solution for too long, the copper plate may melt. For this reason, when the plaque was removed from the solution, it was immediately purged from water or pertinax solution by means of a solution and after making sure that it was thoroughly dried, 35 holes were drilled with a 1.0 mm drill bit to place the circuit elements on the pertinax (Figure 6, Figure 7).

Figure 6. Opening the slots of the components that will be mounted on the circuit

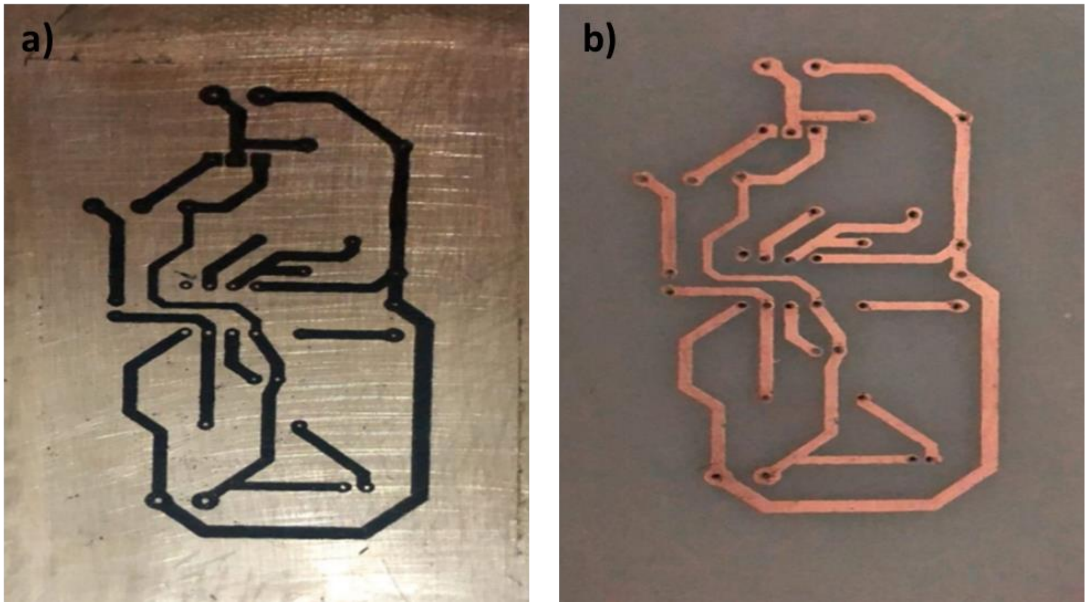

Figure 7. a) The version before Pertinax was thrown into solution. b) A drilled version of the slots after Pertinax is thrown into the solution

After the printing circuit phase was completed, the elements in the circuit were placed on the breadboard and tested with the buzzer mode of the multimeter. As seen in Figure 8, when the red led is on, it is an indication that the circuit is in working condition.

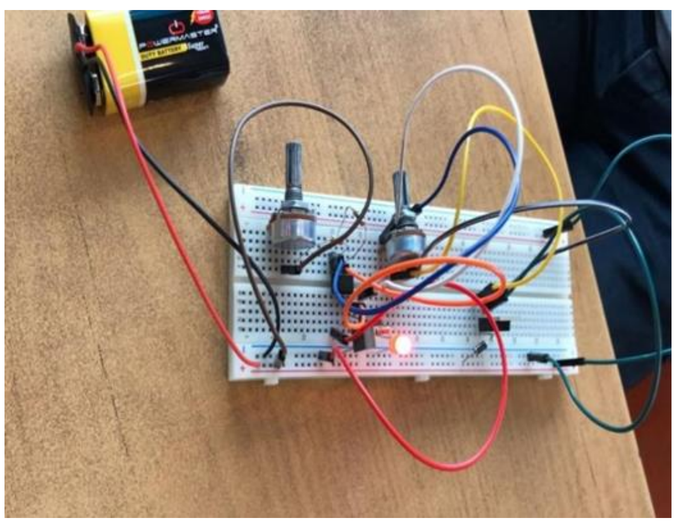

Figure 8. Running the circuit on the breadboard

Circuit elements were placed in the slots opened on the pertinax in the post-stage of the circuit, which was prepared and running smoothly, as indicated in Figure 7, and soldered, and the long legs were cut off as seen in Figure 9.

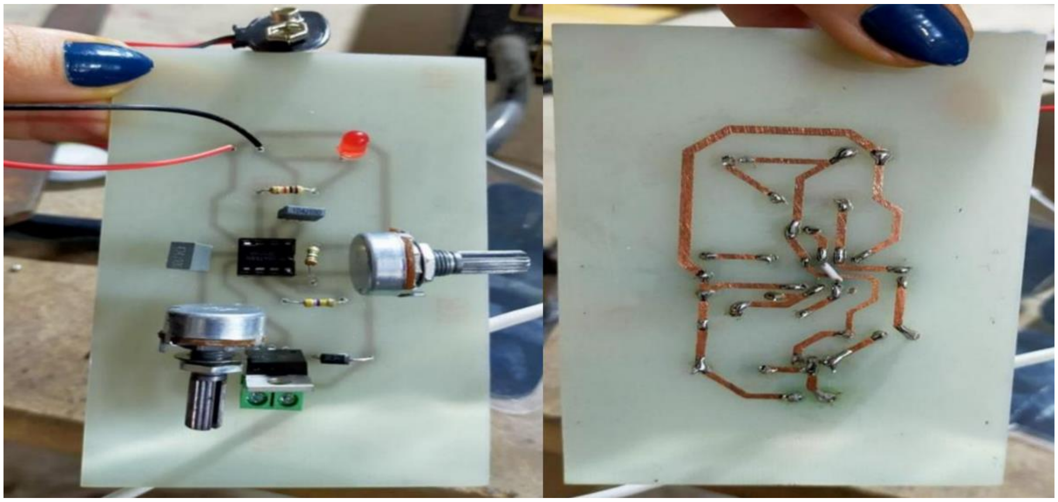

Figure 9. Front view and soldered rear view of the circuit elements on the pertinax

Results

There are two types of users in the designed system. In one use, it is possible to be isolated from the mains and used a mobile with a dry battery. For other uses that require higher current, it is possible to use it by means. While establishing the circuit, the N555, which is inexpensive and easy to access, is used. 1 M pot was used to adjust the frequency of the circuit. The frequency of the circuit is adjusted in the range of 1-100 Hz with the help of a potentiometer. The frequency range can be further increased thanks to the potentiometer. In addition, it has been established in such a way that the amplitude of the output voltage can be adjusted with a potentiometer. The frequency range is adjusted by triggering the N555 with a 1 M resistor and 470 K resistors. The trigger voltage of the 5 K pot IRF640 MOSFET is regulated and the amplitude of the output wave is adjusted. The IRF640 also acts as a switch that triggers the transformer. 0.47 uF capacitor is connected to the reset pin to trigger N555. A 0.1uF capacitor has been added to the circuit to prevent interference with the MOSFET. On the other hand, the 1N4005 diode is used to prevent reverse currents from the transformer. The reason for integrating the transformer into the circuit is that the transformer provides isolation from the body and brings the voltage to the appropriate level. The red led used here is used as an indicator showing the range of signal pulses coming to the probes and it flashes simultaneously with the pulse frequency. In order to prevent the LED from burning, a 1K resistor is added to the circuit. Another purpose of the LED is to act as a stimulus used to show whether the circuit is working or not. The probes added to the circuit transmit signals to the body by providing the connection between the body and the circuit. The task of the two probes available is to complete the circuit. Because one probe acts as a receiver and the other probe act as a transmitter. The human body acts as a transmitter between the two probes.

The BUSER brand TENS device designed in the study was compared with the Fizyopol brand TENS device sold in the market. There are three different programs in the Fizyopol brand

TENS device. These; include TENS mode, EMS mode, and Massage mode. These programs are divided into modes within themselves. There are 9 programs in the TENS mode. Among the reasons for leaving the programs; Sensitivity (pain threshold), which can vary according to the person, the severity of the pain, the location, and the change in the frequency of recurrence can be counted. There are 8 programs in EMS mode and 5 programs in the Massage program. The device has a total of two channels, four electrode outputs, and a pack of 5x5 TENS pads. The frequency of this device is in the range of 1-100 Hz and the output power is 0.120 mA. The designed BUSER TENS device can be used in two modes, and in these uses, the ampere intensity of the device changes according to the type of treatment. The device includes a single channel and 2 electrode outputs. Its frequency is in the range of 1-100 Hz.

In order to observe the time-dependent changes in the electrical voltage between the designed system and the Fizyopol brand TENS device, the differences of the system with standard TENS devices were determined by comparing the current waves on the two-axis graph on the oscilloscope screen. The wavelengths of the Fizyopol brand TENS device connected to the CH1 port of the oscilloscope are shown in yellow in Figure 10. Shown in blue are the wavelengths of the BUSER TENS device connected to the CH2 port. The sine waves produced when the devices send regular current are shown in Figure 10. While the Fizyopol brand sends high currents at regular intervals, BUSER continues to send regular currents. This difference is shown in Figure 10.

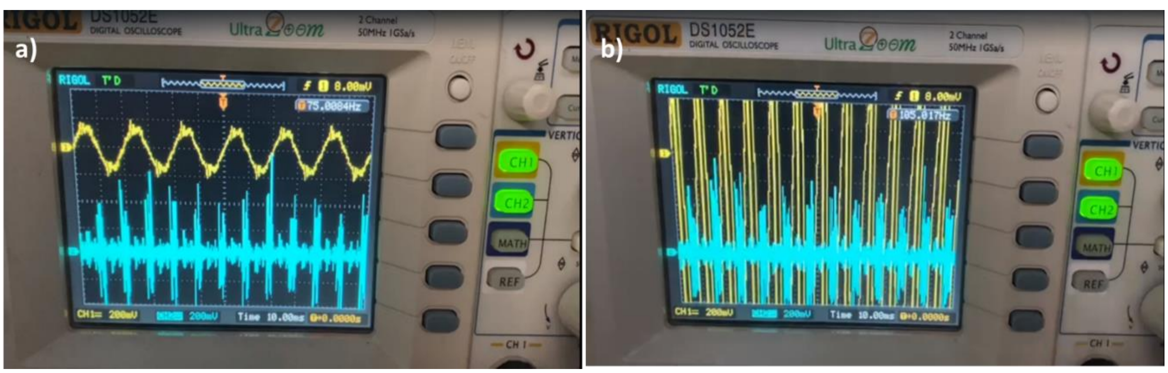

Figure 10. a) Regularly generated sine waves of Fizyopol brand TENS and BUSER TENS. b) Oscilloscope image when Fizyopol TENS device and BUSER TENS device pulse

Discussion

Transcutaneous electrical nerve stimulation (TENS) is a physical therapy method commonly used in the treatment of pain (Vance et al., 2012; Santuzzi et al., 2013). It is used as a technique with successful results in the reduction of fibromyalgia (Dailey et al., 2022), primary dysmenorrhea pain (Arik et al., 2022), shoulder pain (Bilek et al., 2021), back pain (Vella et al., 2022) and chronic cancer pain (Katta et al., 2022). TENS enhances local inhibitory control and is indicated in focal neuropathic pain (NP) (Guastella et al., 2008). The analgesic effect of TENS is similar to that obtained with opioid agonists in the treatment of NP (Kim et al., 2003). TENS is a noninvasive method that is easy to apply with relatively few contraindications.

When Doğan & Kılınçdemir (2017) examined, they aimed to have a low cost, unlike standard and market modules. For this, they designed the TENS device as an analog and used a very inexpensive small circuit working with a 9 V battery in their project. They added the PIC16F877A to the device, which was designed according to the household TENS device and converted from manual use to digital use. In the future planning of their projects, they stated that they could develop the TENS device more professionally by giving an electrical signal that takes the opposite of the pain signal and applies it to the body (Doğan & Kılınçdemir, 2017). In addition to this study, the difference and innovation of the device designed in Buran's study are; It is the automatic application of TENS modalities used in different pain patterns, acting through different mechanisms, to the patient as a program with the help of a microcontroller (Buran, 2002). In the TENS device designed by Uysal to apply to acupuncture points, ardunio has been used for options, integrations, and programming that can be changed for treatment programs suitable for the use of patients. Device; It offers three different options frequency, current strength, and pulse width adjustment (Uysal, 2018). In Güzel's work, she designed the EMS (electrical muscle stimulation) device, which has a TENS-like function. This device has electromagnetic compatibility (SAR) with the human body, which is around 1% of the maximum values (Güzel, 2018). In a study, it was stated that the TENS device significantly reduced pain and improved walking ability in people with knee osteoarthritis (KO) (Wu et al., 2022). Most of the studies have been carried out to confirm that the electrical properties of TENS are consistent with the properties provided by a standard TENS device (Johnson et al., 2022). As we have observed as a result of our literature research, not many innovations have been made on TENS on their own, but steps have been taken to improve it. There are many TENS devices with different features and they apply different wavelength signals according to the type of pain. In this way, pain is relieved without exposing the body to any medication and without side effects. Today, the use of TENS devices has become quite common thanks to this and similar ease of use.

In conclusion, the difference between this designed device from the ones on the market and other works is that it offers the opportunity to be connected to the city network with a system that provides single-channel output with 2 modes for ease of use, as well as the opportunity to be used as a home type with a 9 Volt battery. Thus, the space limit for access to treatment has been eliminated. The device becomes active by opening the power button that starts the electric current. Then, by increasing the current adjusting button, it is ensured that the user reaches the current form that will relieve the discomfort and relax the user. It is possible to make the device more portable by reducing the transformer where the output power is supplied. Modules can be added by adding PIC or other functional programs in the future by making research and observations for the development of the design. A more functional appearance and service can be achieved by developing a dynamic design suitable for the network-connected and home-use versions.

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Author Contributions

Dr. Nur, MSc. Ak, MSc. Levent, MSc. Barış and MSc. Sazaklıoğlu researched the literature and designed the study. They were interested in protocol development, and experimental design. All authors reviewed and edited the article and approved the final version of the article.

Conflict of Interest

The authors declared that no conflict of interest.

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