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GENERATION OF TENS ELECTROSTIMULATOR USING NE555 TIMER

GERAÇÃO DE UM ELETROESTIMULADOR TENS USANDO UM TEMPORIZADOR NE555

GENERACION DE UN ELECTROESTIMULADOR TENS UTILIZANDO UN TIMER NE555

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ABSTRACT

This work consists of the design and implementation of a TENS electrostimulator (Transcutaneous Electrical Nerve Stimulation), which generates its signal with an oscillator created from a NE555 Timer, in which, its shape and signal amplitude can be varied from potentiometers, in order to also modify the frequency at which it will work and which is connected to a power stage with a tip31C transistor, in addition to having its own power source, which connects directly to the alternating current at home, since it has its respective transformers and diode bridge to rectify the signal, also integrating voltage regulators to avoid

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noise and distortions of the signal, and thus be able to generate electrical impulses that can be used in the human body for therapeutic use. Obtaining an electrostimulator that generates an electrical impulse signal for the use of electrotherapy with a preliminary established frequency of 100Hz.

Keywords: Electrical Stimulation. Electrostimulator. Electrotherapy.

RESUMO

Este trabalho consiste no projeto e implementação de um eletroestimulador TENS (Estimulação Elétrica Nervosa Transcutânea), que gera seu sinal com um oscilador criado a partir de um temporizador NE555, no qual sua forma e amplitude de sinal podem ser variadas a partir de potenciômetros, a fim de modificar também a frequência em que irá operar. O mesmo é conectado a um estágio de potência com um transistor tip31C, além de possuir fonte de alimentação própria, que se conecta diretamente à corrente alternada da residência, pois possui seus respectivos transformadores e ponte de diodos para retificar o sinal, integrando também reguladores de tensão para evitar ruídos e distorções do sinal, e assim ser capaz de gerar impulsos elétricos que podem ser utilizados no corpo humano para uso terapêutico. Obtenção de um eletroestimulador que gere um sinal de impulso elétrico para uso em eletroterapia com frequência previamente estabelecida de 100 Hz.

Palavras-chave: Estimulação Elétrica. Eletroestimulador. Eletroterapia.

RESUMEN

El presente trabajo consiste en el diseño e implementación de un electroestimulador TENS (Estimulación Eléctrica Transcutánea Nerviosa), que genera su señal con un oscilador creado a partir de un Timer NE555, en el cual, se puede variar su forma y amplitud de señal a partir de unos potenciómetros, para así, poder modificar también la frecuencia a la que trabajara y que va conectado a una etapa de potencia con un transistor tip31C, además de contar con su propia fuente de energía, que se conecte directamente a la corriente alterna de casa, ya que cuenta con sus respectivos trasformadores y puente de diodos para rectificar la señal, integrando también consigo unos reguladores de voltaje para evitar el ruido y distorsiones de la señal, y así poder generar impulsos eléctricos que pueden ser usados en el cuerpo humano para uso terapéutico. Obteniendo un electroestimulador que genera una señal de impulsos eléctricos para el uso de electroterapia con una frecuencia preliminar establecida de 100Hz.

Palabras clave: Estimulación Eléctrica. Electroestimulador. Electroterapia.

1 INTRODUCTION

Electrotherapy is a process with which electrical stimulation is carried out, whose main objective is to relieve symptomatic pain by stimulating the sensory nerves and together with the pain that it may be causing. That is why today the devices with which these therapeutic processes are carried out have become popular, which what they do is give small electrical impulses and stimulate the production and release of greater amounts of endorphins, whose main function is to analgesic the body causing muscle relaxation.

By definition, electrotherapy is the therapeutic use of electricity. This therapeutic modality has been experiencing a new boom in recent years. Scientific and technological development, the development of new technologies, the development of microprocessors, etc., are marking an evolutionary leap in therapeutic possibilities, which will undoubtedly continue to have a positive impact on the recovery of patients and on the reduction of expenses in medical treatments.

In this modern era, the integration between all areas of scientific knowledge (physics, chemistry, physiology and pathology) is evident, resulting in the possibility of increasingly specific and more personalized treatments. This process is enriched every day with bioengineering and electrophysiology. In addition, electrotherapy has contributed to expanding the field of action of other specialties such as traumatology, sports medicine, cosmetic surgery, etc.

In electrotherapy, it is necessary to know the properties of electrical stimuli and their interaction with biological tissue to achieve the desired effect. Some of the effects sought with the application of electrotherapy are the following: Iontophoresis, functional electrostimulation, analgesic electrostimulation, anesthetic electrostimulation, electrostimulation for tissue regeneration purposes, electrostimulation for thermal purposes, among others.

Currently, our entire society is subject to an evolutionary regime of technology, where different branches come together to develop new technologies. One of the fields in which the application of electronics is essential is the area of medicine, where high-level advances have been presented, thus obtaining an improvement in terms of treatment and diagnosis.

Our country has a minimum index in terms of the development and manufacture of medical instruments, such as in the design and construction of clinical electrostimulator equipment [1], which forces hospitals and medical centers to acquire them in the international market.

Specifically in the area of PHYSIOTHERAPY AND REHABILITATION, the acquisition of equipment is focused on the United States, Japan and Argentina, but with very high prices and without guarantee within our country, in addition, the equipment does not usually meet the needs of buyers, because it is equipment too complex or too simple, without giving the doctor the opportunity to acquire equipment, only with the parameters that he needs, and with an option to update it towards new advances that arise. The work developed by Escalera [2], consists of demonstrating the effectiveness of the modulation of the stimulating signal of TENS therapy (initials obtained from Transcutaneous Electrical Nerve Stimulation) in the treatment of postural mechanoal low back pain, as it presents a more lasting and effective effect than conventional TENS therapy. According to the results, it is shown that both statistically and clinically, a significant decrease in pain is obtained in patients with low back pain 4 postural mechano, when applying TENS therapy with frequency modulation of 50% of the stimulating signal, comparing it with the application of the same therapy without signal modulation. The treatment consisted of the application of the TENS daily, in sessions of 30 minutes for a period of five consecutive days, at the end of these, a rest period of two days was provided and, subsequently, another period of five consecutive days of therapy was carried out. During treatment, patients were not given any drugs or alternative therapies that could interfere with treatment outcomes.

1.1 ELECTROTHERAPY

Electrotherapy consists of the application of electromagnetic energy to the body (in different ways), in order to produce biological and physiological reactions on it, which will be used to improve the different tissues, when they are subjected to a disease or metabolic alterations of the cells that make up these tissues, which in turn form the living human and animal organism in general [3].

The main effects and benefits that occur when applying the different currents used for electrotherapy to the patient are: Anti-inflammatory, Analgesic, Improvement of trophism, Neuro-muscular enhancement, and Thermal, in the case of high-frequency electrotherapy [3].

It is applied in painful, musculoskeletal and peripheral nervous inflammatory processes, as well as in muscle atrophy and injury and paralysis [3]. Electrotherapy is applied under a medical prescription, and is carried out by a physiotherapist or a treatment technique applied in the hands of a Kinesiologist, this, depending on the country.

1.2 ELECTROSTIMULATION

Electrostimulation is the technique that uses electric current to cause a muscle or nerve contraction, this, by means of a device called an electrostimulator, which is used to prevent, train or treat muscles, seeking a therapeutic purpose or an improvement in their performance. Electrostimulation treatments are applied with a device called electrostimulator, which is nothing more than a current generator that produces electrical impulses, with enough energy to generate an action potential in excitable cells: muscle or nerve (sensitive with analgesic and efferent results with excitomotor results), and thus modify their usual state which is rest. The impulse of the electrostimulator, in order to be really effective, must simulate voluntary contraction, reaching the motor neuron with a calibrated electrical charge. The pulses must be calibrated according to two variables: frequency (pulse width in Hz) and chronaxis (pulse width in microseconds).

1.3 TYPES OF ELECTROSTIMULATION

Within electrostimulation, there are different types or techniques for its application.

- **Electro analgesia**. This is a technique aimed at blocking pain impulses that travel through peripheral nerves to the spinal cord and then travel to the brain. Electroanesthesia is based on the Pain Gate Theory of Melzack and Wall [4-5], which states that the painful impulses that travel through the peripheral nerves to the medulla are controlled as they enter the posterior horns of the spinal cord by interfering impulses that are born in non-painful organs, such as: corpuscles of touch, cold, pressure; etc. By stimulating these corpuscles mechanically or electrically, impulses are produced in the respective nerves, which when they reach the medulla block the painful impulses. The specifications of this wave, called TENS, are of a variable current intensity and voltages of 20 to 80 mA or 0 to 70 Volts, in addition to optimal frequencies of 1 to 150 Hz.

- **Electrical muscle stimulation.** The recommended current is a rectangular wave, to avoid the unpleasant and feared polar effects (electrical sensation, skin irritation and even burns), at the location of the electrodes where the current passes. The recommendation is broad, with an onset of 28 mA up to 120 mA or the maximum supportable. Galvanic currents are disconnected, due to the high risk of chemical-electrical burns and the unpleasant sensation of electricity that is perceived at even low intensities.

- **Iontophoresis.** It is a technique to introduce ionizable drugs into tissues by taking advantage of the migration of electrical charges within an electric field of constant polarity, for this, two electrodes are applied in front of the area to be treated; one of the electrodes contains the ionized drug. The drug is placed on the electrode of the same sign as the ion that predominates in it (+ or -) with a constant current source ranging from 1 to 15 mA.

- **Interferential therapy**. The interferential wave stimulator is a piece of equipment that uses medium-frequency carrier sine waves with low-frequency envelopes. Interferential therapy (IFT) is used effectively to manage acute postoperative pain, edema, swelling conditions, and muscle spasms. Interferential stimulation is different from TENS, in that it is a method of suppressing the pain signal going to the brain or to make pain more bearable, activating the body to generate more pain-suppressing chemicals, while IFT treats the causes of pain, as the complications are fewer than those experienced with the use of narcotics for pain relief. Using the IFT accelerates the recovery of patients. The application of this therapy is by means of electrodes, and 2 methods can be used: The Quadripolar Method and the Bipolar Method. Of these methods, the most recommended is bipolar, since quadripole depends purely on the placement of the electrodes, which is not always done optimally. The Bipolar Method uses 2 electrodes, because the waveform is made from the equipment and does not depend on the patient electrode contact. To generate this type of wave, a multiplication of 2 sinusoidal signals is performed, one of low frequency, between 1 and 200 Hz, and the other, of medium frequency, which can be between 3 and 10 KHz, resulting in a modulation in amplitude.

2 ANALGESIC ELECTROSTIMULATION

As part of electrotherapy, there is electrostimulation for analgesic purposes, whose objective, as its name expresses, is to reduce the effects produced by the pain syndrome. Within analgesic electrostimulation, there are some therapeutic modalities that have proven their effectiveness in reducing pain, highlighting among them, TENS therapy in the treatment of postural mechanical low back pain [2]. For the classification of electrotherapy, the following elements are taken into account: the shape, polarity and frequency of the pulses used in the stimulation, in addition to the neurophysiological effects that are desired to be obtained with the application of the therapy.

2.1 ANALGESIC ELECTROTHERAPY

To understand the possibilities of electrotherapy for analgesic purposes, it is essential, first, to know the basic physiology of pain and all the related processes, the morphofunctional characteristics of the receptors, the characteristics of the sensory fibers, the characteristics of the sensory pathways, as well as the aspects related to the perception and inhibition of pain.

2.2 TENS THERAPY

TENS electrical stimulation is a form of low-frequency electrotherapy, which allows stimulation of the thick A-alpha myelinated nerve fibers of rapid conduction. It triggers at the central level, the activation of the descending analgesic systems of an inhibitory nature. It is used to block the transmission of pain to the brain, thus attenuating the sensation of pain, but it is important to emphasize that the cause or origin of the pain has not been cured because the pain does not occur. mainly to decrease pain [6]. The development of TENS is based on the work of Melzack, R and Wall [4-5], on the theory of the spinal control gate and pain modulation. In 1966 the first TENS unit appeared, even today its mechanism of action, treatment indications, optimal placement of the electrodes and treatment parameters are still the subject of research.

It is proven that electrostimulation can help relieve almost all types of muscle pain. What the TENS program does, if any muscle pain occurs, doctors and physical therapists are there to help. Don't self-medicate or overlook an expert's opinion. Thanks to the number of advantages when it comes to attenuating pain and its few disadvantages, we can say that a TENS electrostimulation program is one of the best tools to combat pain, almost or more than a pill.

2.3 DIRECTIONS

In principle, any type of acute or chronic pain, localized and of neurological origin, can be relieved with TENS, as long as the paresthesias can be generated in the symptomatic region. Therefore, the indications are very numerous and, although it was initially only used after the failure of other palliative measures, its effectiveness and, above all, its lack of unwanted effects, make its use advisable as a first-line treatment.

The most frequent indications that TENS can decrease are:

- Dental and inflammatory pain
- Arthrosis
- Headaches and migraines
- Sciatica
- Joint pain
- Headaches

- Back and lower back pain
- Postoperative Pain
- Muscle aches and strains
- Muscle tears
- Sprains
- Herpes Zoster (St. Anthony's Fire)
- Inflammations
- Reactivation of blood circulation
- Tendinitis
- Torticollis
- Trauma caused by bruises or contusions
- Osteoarticular trauma

TENS is an electronic analgesic, which does not solve the pathology, origin of the pain, so it must be treated to prevent the painful sensation from appearing in the future.

2.4 CONTRAINDICATIONS

Low-frequency currents, unlike medium and high frequency, have a number of contraindications that are not excessively high, so it is a highly recommended technique, so it is advisable to follow the indications from a doctor, physiotherapist or physical trainer expert in the subject. This method, although it does not affect blood pressure or heart rate, does limit its use to people who have any of the following characteristics [7]:

- It should not be applied to people with pacemakers.
- It should not be applied in people with tumors and metastases.
- It should not be applied to people with thrombosis, thrombophlebitis and varicose veins.
- It should not be applied to diabetics and epileptics.
- It should not be applied to people with sensation disorders.
- Do not use near the carotid. Low blood pressure can cause the patient to faint.
- Do not use in people with bleeding processes.
- Do not use in febrile and/or infectious states.
- Do not use on the abdomen in pregnant women.
- Do not use in hypersensitive or very nervous people.
- Do not use on children under 10 years of age.

In the present work, the design and implementation of a TENS electrostimulator will be carried out, which generates its signal with an oscillator created from a NE555 timer [8-

10], with a tip31C transistor and that has its own energy source that generates an electrical impulse signal for the use of electrotherapy with a preliminary frequency of 100Hz.

3 METHODOLOGY

An oscillator circuit is a circuit that produces square wave signals (or digital signals). These signals alternate between switching on and off.

This is important, because many different types of chips need digital signals to operate, such as digital potentiometers, and other types of integrated circuits. These digital signals provide a way for a master and slave device to act in sync with each other. Whether it's on the falling or rising edge of a digital signal, the 2 devices will work in sync so that they can produce the desired result.

With a 555 timer, digital signals of different frequencies can be produced based on the values of the chosen external resistors and capacitor.

Digital signals of any necessary frequency can be produced. For example, a 1Hz signal will be triggered once per second. A 2Hz signal will be activated every 0.5 seconds. A 100 kHz signal will be activated every 0.00001 seconds or every 10 microseconds. The time period, $T= 1/f$, where f is the frequency of the signal.

In order for the 555 timer to work, it must be operated in stable mode. Astable mode is a mode in which there is no steady state. The circuit is constantly changing from low to high, which is representative of a digital square waveform that constantly goes from high to low, high to low, high to low, over and over again. So, the astable mode constantly switches between high and low states. This is in contrast to the other 2 modes, monostable mode and bistable mode. Monostable mode has a state, high or low. The bistable mode has 2 stable states that can be inside. Like the astable mode, the bistable mode has 2 states, but they are stable; In astable mode, they constantly fluctuate between the two states.

A 555 timer is very versatile. An oscillator of approximately 60Hz can be generated, where the cycles are 60 times per second. The components that are required are:

1 timer 555

1 resistor at 1MΩ

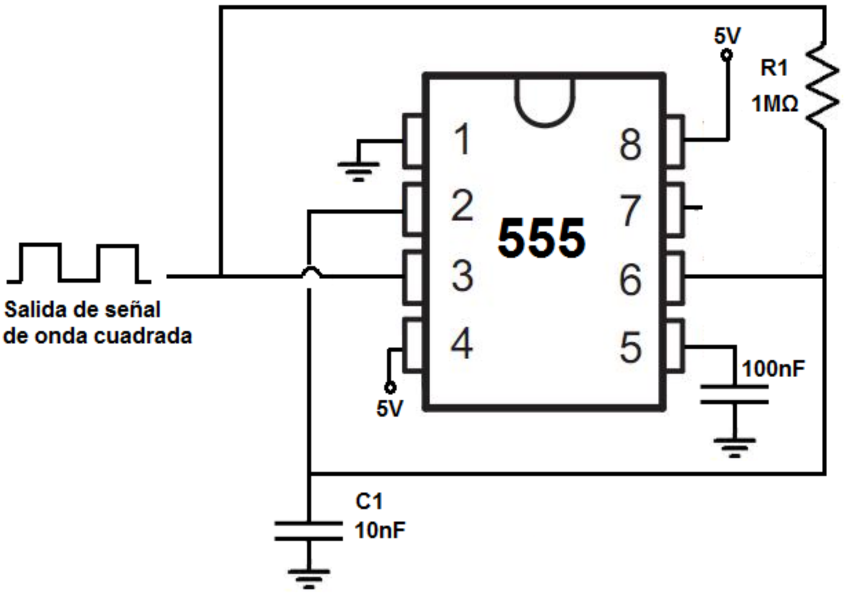
1 capacitor at 10nF

1 capacitor at 100nF

The 555 timer can be obtained at a very low cost, in almost any electronic distributor. The 555 timer is an 8-pin chip. On this circuit, the 555 timer to be in astable mode. In this mode, the 555 timer will go from HIGH to LOW, HIGH to LOW, HIGH to LOW, mimicking a digital square waveform, which can be used as a clock. The oscillator circuit that will produce 60Hz signals using a 555 timer is shown in Figure 1.

Figure 1

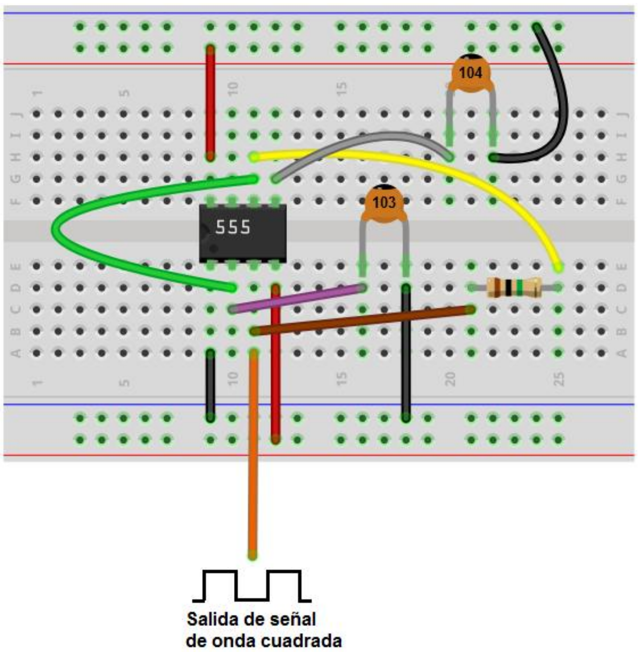
60 Hz oscillator circuit



Below is the proposed scheme to be developed on a breadboard (figure 2)

Figure 2

Diagram of the connection on a Breadboard of the 60 Hz circuit



The astable mode can produce digital square waveforms that go back and forth between HIGH and LOW.

Then you have a signal, with an approximate frequency, since in the 60Hz circuit, you have to take into account the tolerances of the resistors, since they can fluctuate a little above or below this level. And that's right, how you can create an oscillator with a 555 timer.

If you want to measure the output directly and you have an oscilloscope, all you have to do is connect the positive terminal of the oscilloscope to the output terminal 3 of the 555 timer, and the negative terminal to ground. An image of the digital square waveforms should then be obtained on the oscilloscope. And then, you can see the frequency and the length of time that a cycle lasts.

There are multiple ways this circuit can be tested. If the values of the resistor or capacitor were to be changed to create a much higher frequency signal, then it would not make sense to connect it to an output, such as an LED, because the human eye would not be able to catch it. The only thing you can do to measure the circuit would be to connect it to an oscilloscope that can measure such high frequencies.

Here are some variations of the parameters.

To create a 6Hz signal, R1= 10MΩ and C= 10nF.

To create a 600Hz signal, R1= 100KΩ and C= 10nF.

To create a 134Hz signal, R1= 470KΩ and C= 10nF.

To create a 1.7KHz signal, R1= 33KΩ and C= 10nF.

To create a 43KHz signal, R1= 1KΩ and C= 10nF.

To create a 180KHz signal, R1= 150Ω and C= 10nF.

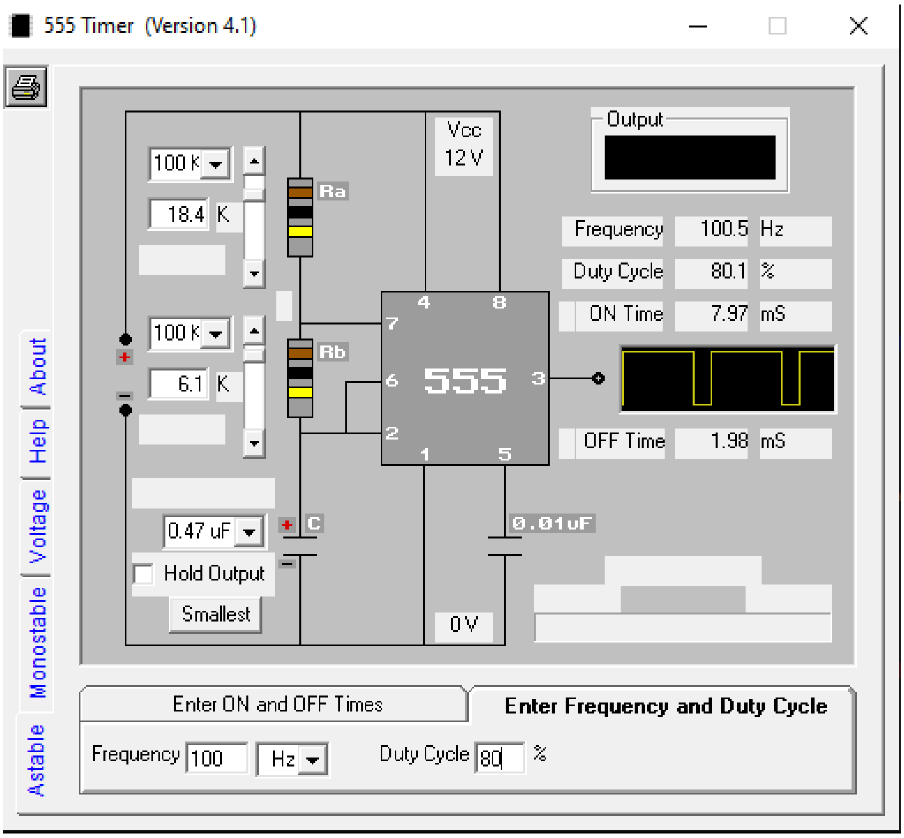
To create a signal of 252KHz, R1= 100Ω and C= 10nF.

One of the problems that we have in this work initially is how to determine the values that the resistors and capacitors that are adapted to the NE555 circuit of the electrostimulator should have. To solve this, you need to use the 555 Timer 4.10 application [11], which is a free application that can run on Windows XP, Windows Vista, Windows 7, Windows 8 or Windows 10, which was originally created by Andy Clarkson. This program allows you to calculate the values of resistors and capacitors for Astable and Monostable modes

In the present work it is desired to generate a signal of approximately 100 Hz, it is for this reason that it is necessary to define which resistors and capacitors will be adapted to the NE555 circuit. To carry out this, the 555 Timer 4.10 application was used, where the duty cycle of 80%, the frequency of 100 Hz fed with a Vdc voltage of 12 V were defined, this process can be seen in Figure 3. It was found that two resistors of 18.4 kΩ and 6.1 kΩ and a capacitor of 0.47 μF are required, adapted to the NE555 circuit, resulting in a square wave of 8 ms on and 2 mS off.

Figure 3

Capturing the 555 Timer application using an astable timer with a frequency of 100 Hz and an 80% duty cycle



3.1 OSCILLATOR CIRCUIT SIMULATION

To carry out the simulation we use the Proteus program, because it is a software that allows the construction of electronic equipment in all its stages: from designing the electronic schematic, programming software for the use of microcontrollers, performing the construction of the printed circuit board, simulation of electronic diagrams, debugging of errors, among many other functions [12].

The components used in the simulation of the circuit to obtain a frequency of 100Hz were:

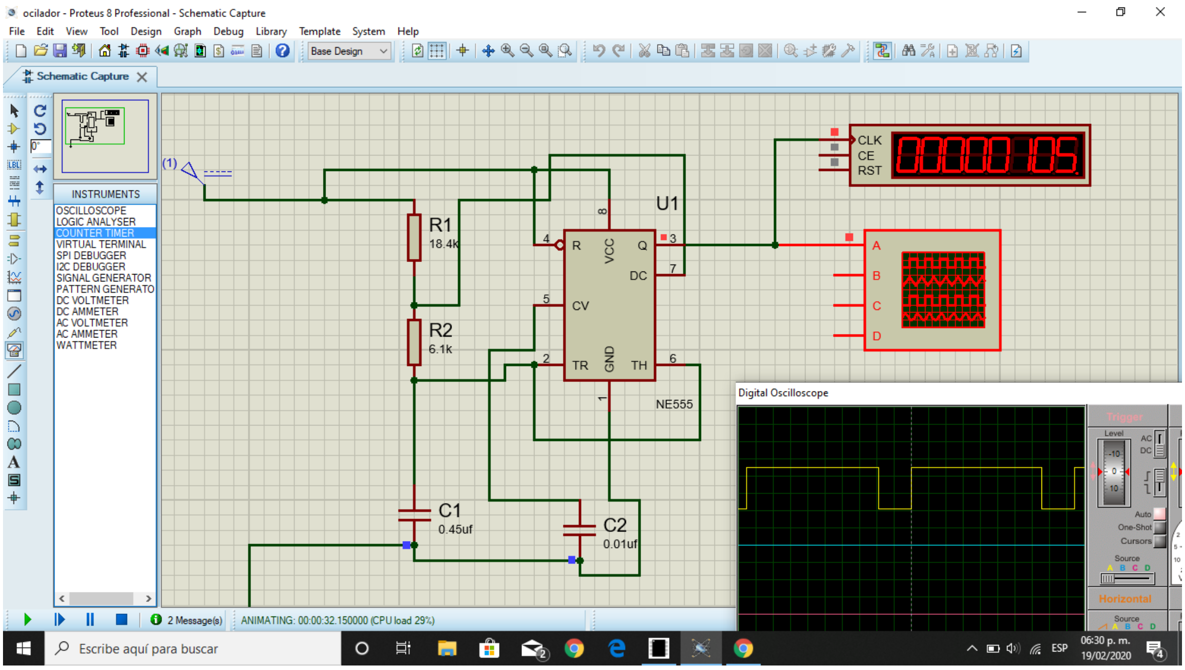
- A Ne555 timer
- A resistance of 18.4 kΩ
- A resistance of 6.1 kΩ
- A 0.01 μF capacitor

- A 0.45 µF capacitor
- An oscilloscope
- A timer counter

The results of the oscillator circuit simulation are shown in figure 4, where the circuit allows to generate a square signal with a frequency of 105 HZ, this allows us to define the components that constitute the oscillator circuit that the electrostimulator will have.

Figure 4

Oscillator circuit simulation with an 80% duty cycle



The methodology for the design and generation of an electrostimulator consists of the stages described below.

a) In the first stage, the device that allows us to generate the initial signal of the electrostimulator is generated.

b) In the second stage, the power source that will power the electrostimulator is generated.

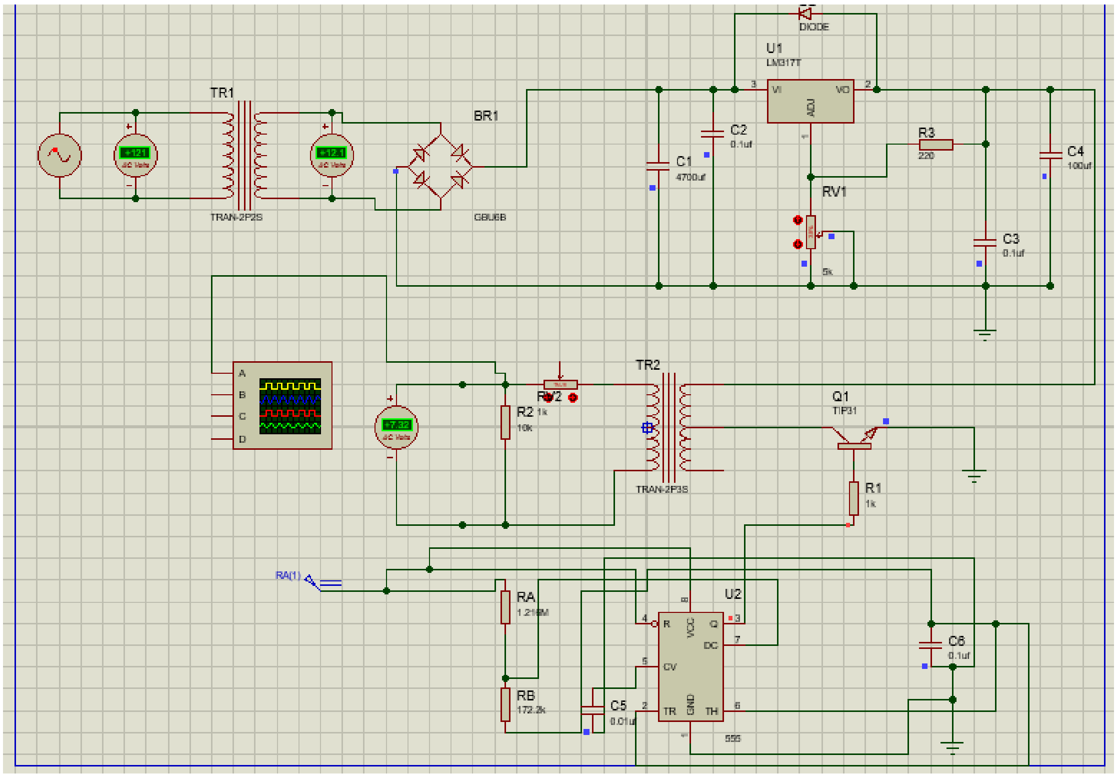
c) In the next stage, signal amplification takes place.

d) Finally, the electrostimulator is performed.

Regarding the first stage, it is proposed that the device that generates the initial signal is an oscillator circuit generated with a timer 555 in astable mode (this was described in the previous chapter). Figure 5 shows at the bottom, the part of the device that allows the electrostimulator signal to be generated.

Figure 5

Simulation in the Proteus program of the complete circuit of the electrostimulator



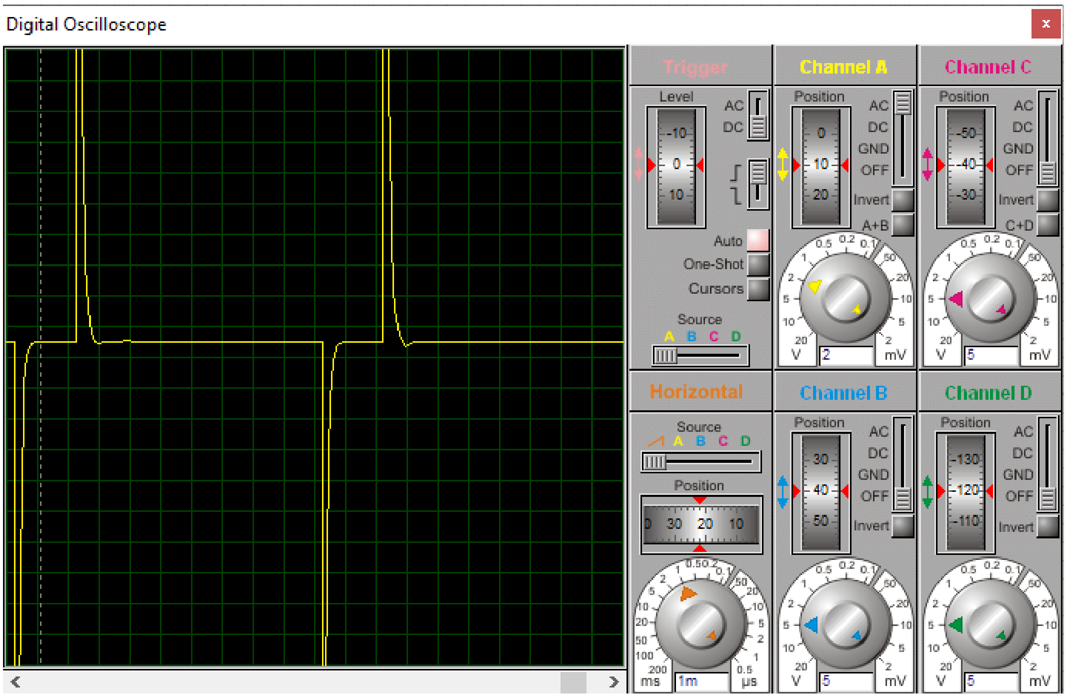
The second stage, which can be seen in Figure 5, and which is located at the top, includes the simulation part of the power supply. The power supply has an alternating current socket of approximately 120 V, for which a reduction stage is required, this can be carried out by means of a transformer from 120 to 12 V, which allows the voltage of the alternating current to be reduced, then, the rectification of the voltage from alternating current to pulsating direct current is carried out. This is done by means of a diode bridge. Then, there is a variable voltage regulator, so that, with a potentiometer, you can have control of the output voltage, and finally, it is connected to a transformer from 12 to 120 V.

In another stage, we have a voltage regulator connected from the output of the diode bridge to the oscillator, this, in order to stabilize the 12 volts without noise, the oscillator that generates a frequency of 100Hz, is connected as seen in figure 5, with potentiometers to be able to vary the duty cycle, to the output of the oscillator is connected the amplification stage with a tip31c, and in turn, it is connected to the middle winding of the transformer from 12 to 120 V.

When carrying out the corresponding simulation, as can be seen in Figure 6, an asymmetric biphasic signal with a frequency of 100 Hz was obtained by means of the digital oscilloscope that Proteus has, which is what is required for the good performance of a TENS electrostimulator [13].

Figure 6

Results obtained on the oscilloscope of the simulation



4 DEVELOPMENT AND IMPLEMENTATION

The following materials are required to generate the prototype of the electrostimulator:

2 x 120:12 V transformers

1 2nd diode bridge

1 x 4700 μF capacitor

3 x 0.1 μF capacitors

1 x LM317 voltage regulator

1 voltage regulator

1 diode

1 x 5k potentiometer

1 Resistance of 220 Ω

1 x 100 μF capacitor

1 timer NE555

1 x 0.01 μF capacitor

1 x 50k potentiometer (fixed at 18.4k)

1 x 50k potentiometer (fixed at 6.1k)

1 x 1kΩ Resistor

1 x TIP31C transistor

The following stages were required to assemble the prototype of the electrostimulator:

4.1 SIGNAL ADAPTATION AND REGULATION STAGE

In the stage of adapting the signal or regulating the electric current, what is done is to receive an alternating current signal of 120 V, then, with the help of a transformer, the voltage is reduced to 12 V, in turn, this transformer is connected with a diode bridge, which allows the alternating current to be converted to direct current. To carry out the adaptation and control of the signal, variable voltage regulators are used to control the output voltage of the electrostimulator, for this, capacitors were added to the input and output of the regulator, this, in order to avoid voltage spikes and thus be able to obtain a better signal without noise, In addition, a 5 K potentiometer is used in the regulator's adjustment terminal, which has a terminal connected to the adjustment terminal and another ground terminal, in the same adjustment terminal, a 220 Ω resistor is connected, which in turn is connected to the regulator's output voltage terminus.

4.2 SWING STAGE

In the oscillation stage, a Ne555 timer is used, which can work with low frequencies, which allows the electrostimulator to be used with people at the time: The Ne555 timer has an array of connections established in its data sheet that allows calculating the resistances necessary to obtain the desired frequency. In this work, instead of resistors, we use potentiometers to be able to modify the amplitude and frequency of the signal, as well as its duty cycle, the timer has 8 terminals, of which, terminal 1 is connected directly to ground, terminal 2 is connected to a potentiometer and a capacitor of 0.1μF, which in turn, the capacitor is grounded, and the potentiometer is connected to another potentiometer, and then to 12V terminal 3, which is the output terminal

Terminal 4 is connected to 12 V, terminal 5 is connected to another 0.01 μF capacitor, and the capacitor is grounded, terminal 6 is connected to terminal 2, terminal 7 is connected to the midpoint between the 2 potentiometers, and finally, terminal 8 is connected to 12 V.

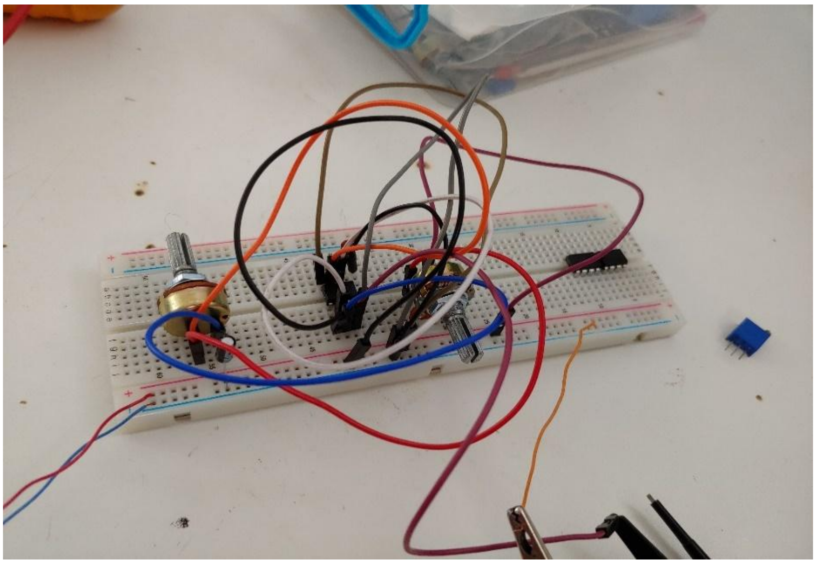
4.3 POWER STAGE

Finally, the power and signal output stage is made up of three components, a 120:12 transformer, a tip31c transistor and a 1 kΩ resistor, which allows the transistor to be triggered, the 1 kΩ resistor is connected to the oscillation stage at terminal 8 of the Ne555 timer, the resistor in turn, It is connected to the base terminal of the transistor, the connector terminal is connected to the middle winding of the transformer, and the emitter terminal of the transistor is grounded, the other terminal of the transformer is connected directly to the output of the voltage regulator so that the other winding of the transformer can be used as output.

The prototype of the electrostimulator developed in this work must generate a square pulsating signal of low frequency, approximately 100 Hz, to verify this, in Figure 7 you can see the part of the prototype that comprises only the signal generation stage.

Figure 7

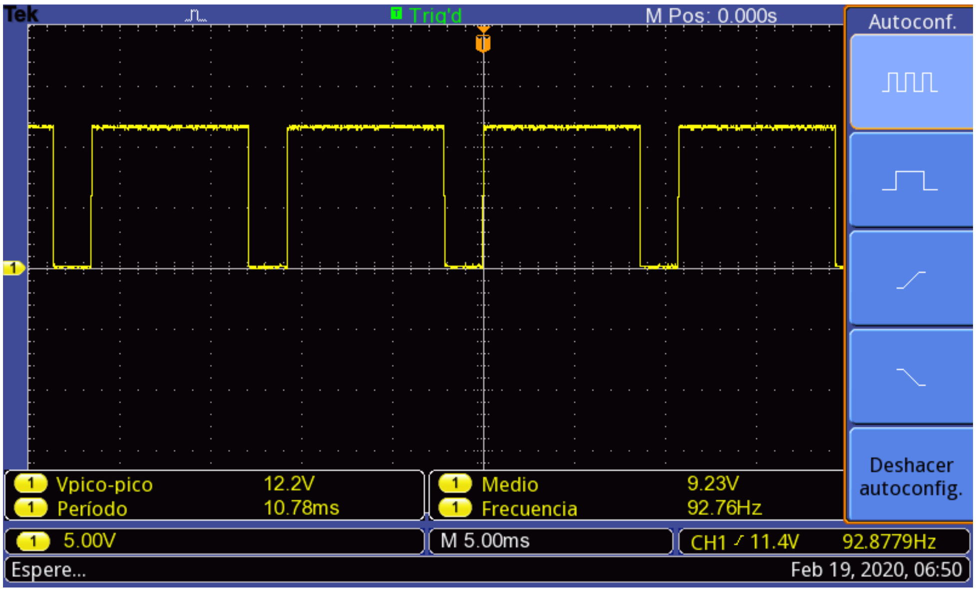
Prototype oscillator with Ne555



When analyzing the signal generated with an oscilloscope, a signal working at 92.76Hz with a peak voltage of 12.2 V and a duty cycle of 80% was obtained (Figure 8). Finding with this, that it was possible to verify and validate the signal generator of the TENS electrostimulator, since, based on the schemes and simulations proposed in this work, a square pulsating signal is generated as the one obtained by means of the simulation in Figure 6. and, on the other hand, a pulsating square signal can be generated with a frequency of approximately 100 Hz.

Figure 8

Oscilloscope Results of the Oscillator Prototype



In this work, the prototype of the TENS electrostimulator (Figure 9) was completely designed, completely guided by the scheme present in Figure 5. With this prototype, tests were carried out with an oscilloscope to verify and validate the output signal of the device. The verification and validation process of the prototype could be demonstrated, since the output signal of the prototype is the same as the one obtained through the simulation as shown in Figure 10, which is an asymmetric biphasic signal, with an approximate frequency of 100 Hz, which is required for the good performance of a TENS electrostimulator [17].

Figure 9

Integration of the complete circuit of the Electrostimulator

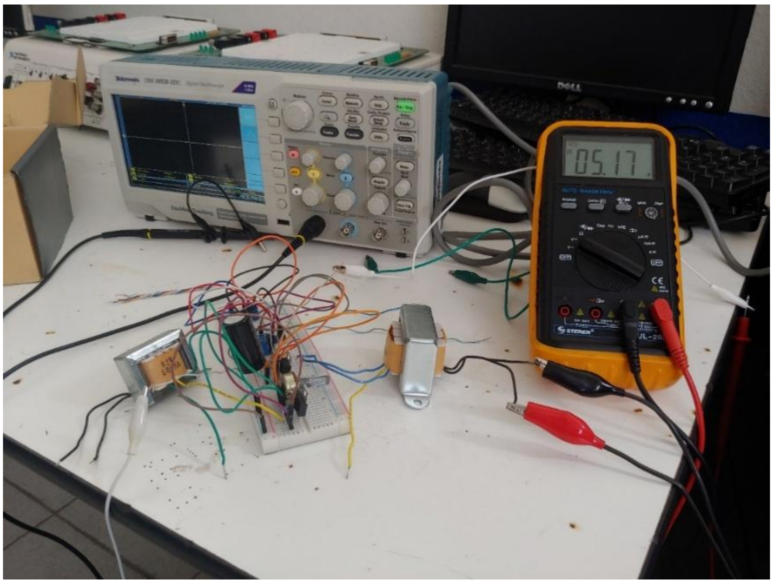
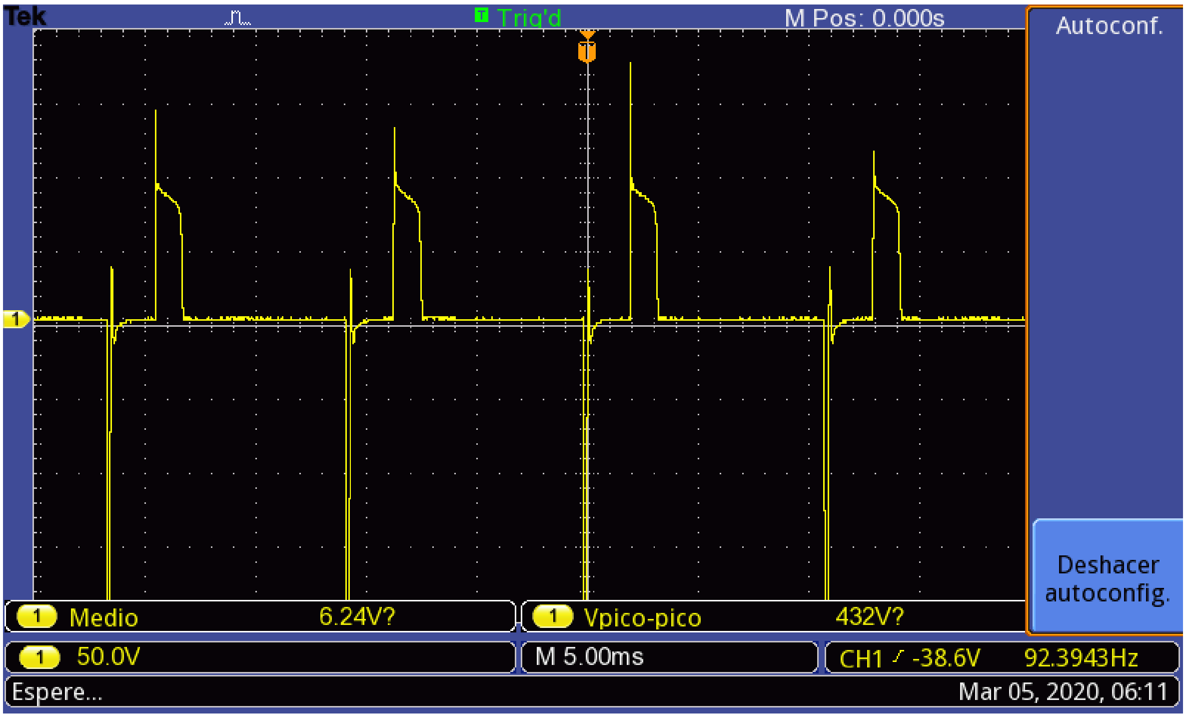


Figure 10

Signal obtained from the output of the electrostimulator



5 CONCLUSIONS

The main conclusion in this work is that the main objective was fulfilled, which was to build a TENS electrostimulation equipment, which can produce an asymmetrical biphasic signal, with an approximate frequency of 100 Hz, which, when applied in a therapy to a person, can help block the transmission of pain to the brain. thus attenuating the sensation of pain.

It was also possible to create a device from the NE555 integrated circuit, which was one of the most important stages to control the frequency of the electrostimulator to be able to vary its frequency, which was one of the main objectives of the development of this thesis.

With this prototype we can demonstrate that devices can be created for use in people at a low cost and with the specifications that government institutions require to be for medical use.

The device is specific for use in the home network, but that is why it has an integrated power supply, but it could be modified and thus reduce its production costs if it were replaced by batteries.

The perspectives of this work are:

- Generate a user-friendly interface.
- Manipulate the electrostimulator using an application on a mobile device.
- Include a screen that shows us all the information about the electrostimulator

- Generate a specific microcontroller for the use of the device.
- Propose an alternative version with batteries
- Production for use in gymnasiums of the Autonomous University of Zacatecas "Francisco García Salinas".
- Reduce the size of the device by making a better arrangement of the components.

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