

A LOW IMPART MUSCLES STIMULATOR FOR NIGERIAN ECONOMY

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Abstract

This paper presents a low impart muscle stimulator, designed to provide help and relieve for the people with certain types of chronic and acute pain. The circuit consists of variable energy tank, switching circuit power supply, the astable multivibrator and pulse generator electrode. These are connected to produce current of low intensity, low frequency and a short path during application to the human body. The stimulator initiates muscle contraction and increases the muscle tone of the human body. The mass production of this design will improve the Nigerian economy.

Introduction

Pain affects the quality and enjoyment of life. Pain is the suffering of body or mind. Pain warns the body of injury. This warning system is intended to prevent additional damage. The sensation of pain is important because without it, vital parts of the body may be injured without one knowing (Mills, 2000). However, persistent pain often called chronic pain, once diagnosed serves no apparent purposes.

This low impart muscle stimulator has been designed to help relieve people with certain types of chronic and acute pain. This stimulator is an electrical device use to initiate muscle contraction and increase muscle tone. It can also be called transcutaneous electric nerve stimulator, which refers to the transmission of small electrical pulses through the skin to the underlying peripheral nerves. This is based on the principle that by stimulating the body, it causes the body to generate its own natural pain control mechanism. Thereby reducing the pain messages sent to the brain. This device finds its application in Electrotherapy, a branch of physiotherapy, which involves the use of electric current to treat disease (Lapedes and Parker, 1997). Low frequency electrotherapy uses relatively weak alternating electric currents. They are delivered by electrodes that are placed under or on the surface of the body and are connected to pulse shaping circuits that are located inside or outside the body. Surface electrodes are widely used for the relief of pain in excitable cells such as those on the muscle and nerve tissues. It is important to note that this device does not offer electric shock, unconsciousness or death produced by the passage of electric current through the body. The effect of electric shock on the human body is determined by the following factors:

- i. The current intensity.
- ii. The path of the current.
- iii. The duration of the current.

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Hence, the low impact muscle stimulator deals with current of low intensity and low frequency for a short path application. The frequency used is 0.6 – 4 Hz, which will be suitable to the human body. The circuit is protected against overload, to ensure a low current of microampere is supplied, so the patients' safety is insured and assured.

The Low Impact Muscle Stimulator

The Low Impact Muscles Stimulator can be broken down into 6 blocks as shown in fig. 1. The blocks are:

1. Power supply unit
2. Variable Energy tank
3. Variable low frequency pulse generator
4. Switching circuit
5. Step up transformer
6. Output sensor

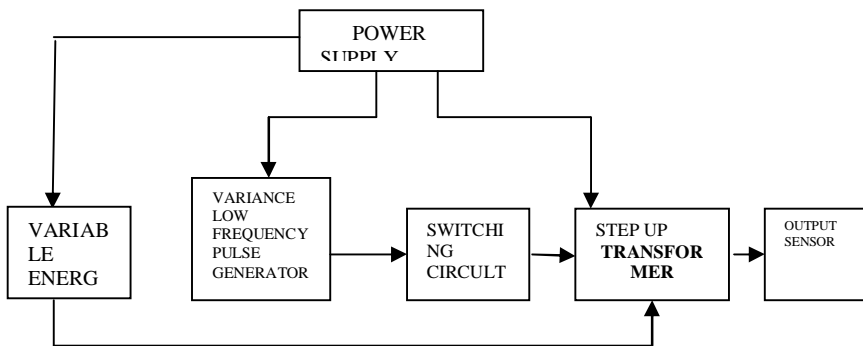


Fig. 1: Block diagram of Low Impact Muscle Stimulator

Power Supply Unit

This low impact muscle stimulator is designed to operate at a power supply of 9 volts direct current (dc.). This is achieved by the use of battery or the stepping down of the voltage from the supply mains which utilizes regulator, rectifier and capacitor to arrive at the desired voltage. The power supply unit comprises of the transformer, rectifier, filter and regulator as shown in fig. 2.

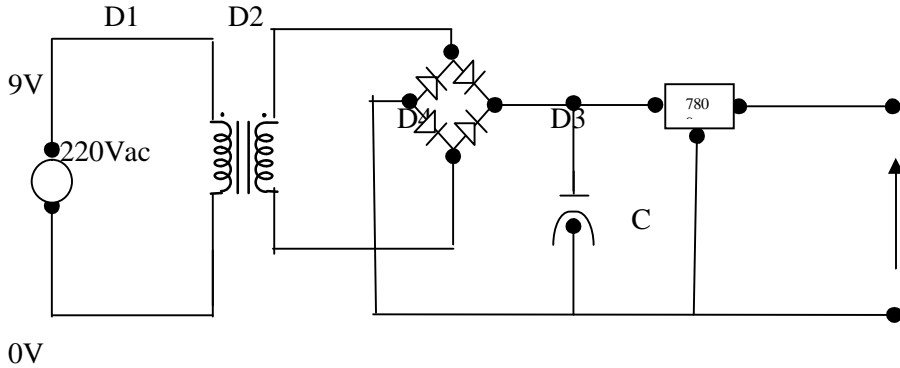


Fig. 2: Diagram of Power supply unit.

The Transformer

The transformer is step down transformer, transforming the 220V (a.c) at the input terminal to 12V, since a 9V supply is required by the system.

The Rectifier

This is a bridge rectifier where the alternating input to the bridge is rectified to a direct current output hence, rectifier chosen is IN4001.

The Filter

The filter is a capacitor connected across the output of the rectifier bridge. This capacitor smoothen the output of the rectifier to give a smooth dc voltage at minimum ripple. The value of the capacitor is 1000 μF. This value is given by the relation:

$$C = \frac{1}{\sqrt{3FR_{rf}}}, \text{ where}$$

C = is capacitance

F = is the frequency of the main supply voltage in hertz

R = is the resistance of the overall circuit to be powered

The Regulator

This is an Integrated Circuit (IC) that gives a current voltage, which is ideal for stand alone power supplies. The regulator is of the 78' series having a 1.5A output current and 7809 has been chosen in particular since 9V is desired at output of power supply unit.

Variable Low Frequency Pulse Generator

This is the heart of the whole design where pulses are generated at very low frequency ranging from 0.6-4Hz. This frequency is also designed to be variable within its range. The 555 timer is one of most universal IC. It has been remarked into a number of different technologies. The two primary versions are the original bipolar design and the more recent Complemented Metal Oxide Semiconductor (CMOS) equipment. These differences primarily are the amount of power they require and their maximum frequency of operation. They are pin-compatible and functionally interchangeable. The 555 timer IC can operate in either monostable or astable mode depending on the connection and the arrangement of the external components. Thus, it can either produce a single pulse when triggered or it can produce continuous pulse train as long as it remains powered (Paul and Winfield, 1995). For the purpose of the design, the astable mode is employed as shown in fig 3.

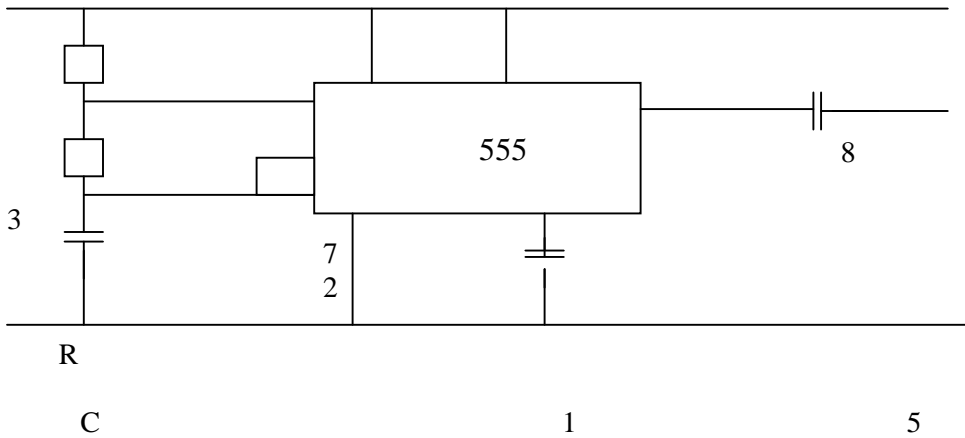


Fig 3: 555 timer connected as an astable Multivibrator

The time for which the output is high, T_1 is given by $T_1 = 0.693C [R_1 + R_2]$

And the time for which the output is low; T_2 is given by $T_2 = 0.693R_2C$.

The period $T = T_1 + T_2 = 0.693C [R_1 + 2R_2]$.

The Frequency $F = 1/T$

$$F = \frac{1}{0.693C(R_1 + 2R_2)}$$

If R_2 is much larger than R_1 then the mark/space ratio is approximately equal to one. The frequency is measured in hertz if the resistance is measured in ohms and the capacitance in farads. The device is to generate a pulse at low frequency of

0.6HZ \longrightarrow 4HZ

Let $R_1 = 10 \text{ K}\Omega$

$C = 10 \mu\text{F}$

To obtain R_2 i.e. $R_2 = \frac{1}{2}[1.44/FC] R_1$

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At maximum frequency of 4 Hz

$$4 = 1.44 / [10 \times 10^2 + 2R_2] (10 \times 10^{-6})$$

$$R_2 = 1/2 [1.44/4 \times 10 \times 10^{-6} - 10 \times 10^{-6}]$$

$$R_2 = 13,000 \Omega$$

$$R_2 = 13,000 \Omega$$

$$\longrightarrow R_2 = 10 \text{ K}\Omega$$

For the minimum frequency of 0.6Hz,

$$R_1 = 10 \text{ K}\Omega$$

$$C = 10 \mu\text{C}$$

$$R_2 = 1/2 [1.44/FC - R_1]$$

$$R_2 = 1.44/2 \times 0.6 \times 10 \times 10^{-6}$$

$$= 120,000 - 5000.$$

$$= 115,000 \Omega$$

But this value is not available therefore,

$R_2 = 100,000 \Omega$ which is commercially available.

Variable Energy Tank

This unit is made up of capacitors; the capacitor is used to store energy which will be discharged later and supplied to the transformer.

The energy stored in a capacitor Q is given by:

$$Q = 1/2 CV^2$$

where Q is the energy, C is the capacitance and V is the voltage across its terminal (Boylestad and Nashesiky, 1987).

Thus:-

The capacitance will be calculated for a voltage of 9 volts and energy value of 0.4mj.

$$Q = 1/2 CV^2$$

$$0.4 \times 10^{-3} = 1/2 C [9]^2$$

$$C = 9.876 \times 10^{-6} \text{ F}$$

Therefore C is taken to be 10 μF .

Switching Circuit

This switching circuit is made up of a transistor employed in the switch mode. In this mode, the transistor operates between the cut off and saturation regions. The design requirement of this circuit is for the transistor to have low power consumption, a typical current of 150nA.

From the data sheet of semiconductor, the BC 337 transistor was chosen since it met all this requirements.

At saturation

$$V_{CE} = V_{EE} [\text{sat}] = V_O = 0.2\text{V}$$

$$V_O = V_{CC}, I_B \leq 0$$

The transistor will remain cut off until $V_{in} \geq V_{BE} = 0.7\text{V}$ i.e. $V_{in} \geq 0.7\text{V}$, $I_B = 0$, the transistor moves from cut off to linear active region. As the base current I_B is increased, the transistor gradually moves towards saturation.

Just before saturation, called the edge of saturation [EOS] (Fitzgerald, 2000)

$$I_{B [EOS]} = \frac{V_{in} - V_{BE(ON)}}{R_B} \quad (1)$$

$$I_{C [EOS]} = \beta I_{B (EOS)}$$

Taking the equation of the path to ground,

$$\begin{aligned} V_{out} &= V_{CC} - I_C R_C \\ &= V_{CC} - \beta I_B R_C \end{aligned} \quad (2)$$

Substituting eqn. (1) into eqn. (2) yields

$$V_{out} = V_{CE} - \beta \left(\frac{V_{in} - V_{BE}}{R_B} \right) R_C$$

This equation holds for the whole active region down to EOS region

Step Up Transformation

A transformer is an electromagnetic device which transforms one alternating voltage level to another. Transformers are used both in Power Systems and Electronics. In Electronics, transformers are used to step the main supply voltage down to one, which is suitable for semi-conductor device say [5 V or 15 V]. In this design, a step down transformer is used in the reverse [step up]. This is basically because the pulse generated, are of very low value and as such, when stepped up, lowers the current.

Transformer rating: 220 V/ 6 V

Power rating = 1.5 VA

Since the power at the input = power at the output,

Current at the output I_1 is given by

$$6 \times I_1 = 1.5$$

$$\text{Therefore } I_1 = 1.5/6 = 0.25 \text{ A} = 250 \text{ mA}$$

The power at the input is also 1.5 VA, hence, the current I_2 is given by

$$220 \times I_2 = 1.5$$

$$I_2 = 1.5/220 = 0.0068 \text{ A} = 6.8 \text{ MA}$$

this is a safe current level.

Output sensor

The output sensor serves as the contact point of this device [low impact muscle stimulator] to the muscle. This sensor is made up of electrodes through which electric current enters or leaves a conducting medium.

The complete circuit diagram is shown in Fig. 4.

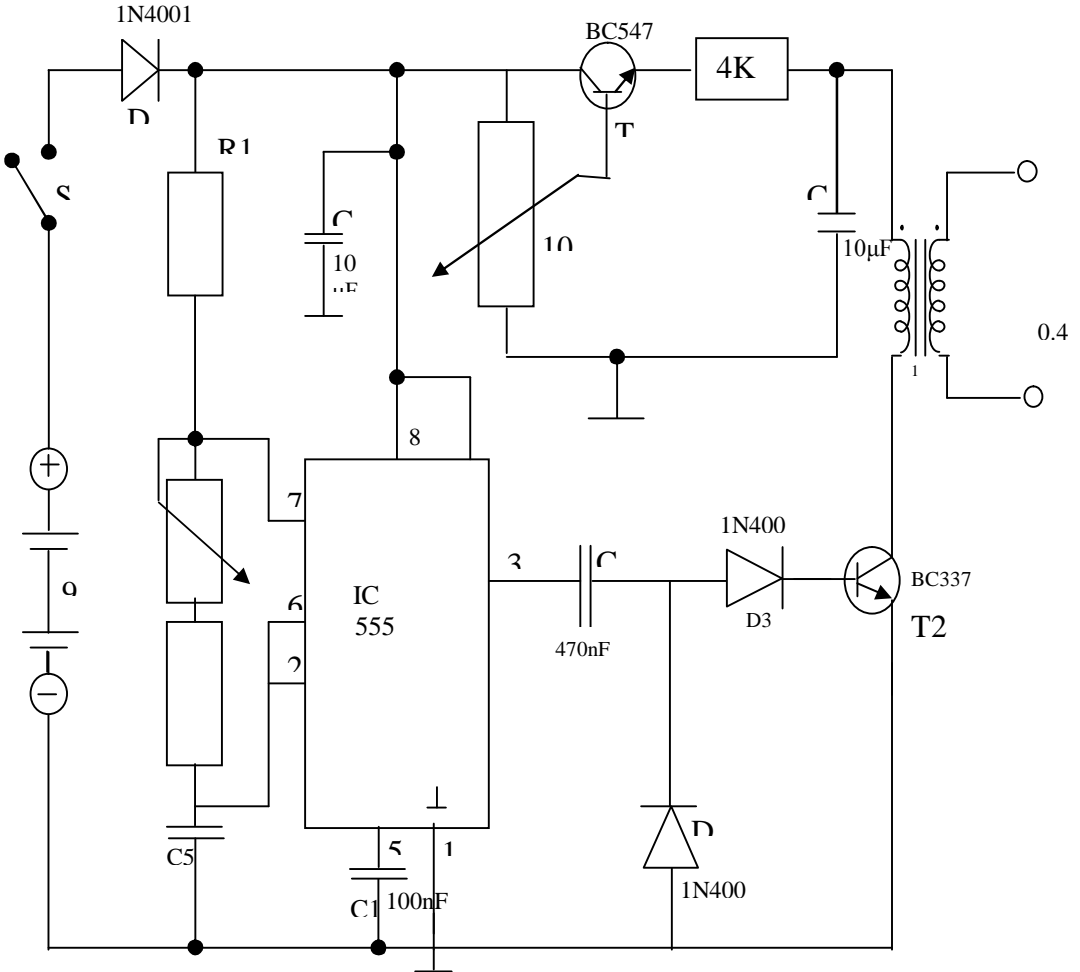


Fig. 4: Complete Circuit of Low Impart Muscle Simulator.
Source : Tenebe Patrica (2004)

Results and Discussions

The results obtained are tabulated below:

Points	Result (voltage)
Mains	230V
Transformer	12.5V ac
Rectifier output	9.02V
Dc ground	0V

Since the Low Impart Muscles Stimulator has been tested and is working well, there is the need to mass-produce it so that those hurting will have access to it. It will improve Nigerian economy in the following ways:-

1. It will save our foreign exchange used in buying similar stimulators from outside Nigeria.
2. It will create jobs for Nigerians mass producing them.
3. It can be exported to other countries thereby, increasing the income of the country.
4. Since it will be affordable by most Nigerians, it will be in every home to help those hurting, therefore helping to reduce mortality rate.

Conclusion

The Low Impart Muscles Stimulator has been presented. It will help people with certain type of chronic and acute pain. It initiates muscles contraction and increases muscles tone. This design, like other designs in laboratories and libraries in Nigerian Higher Institutions, can be mass produced in Nigeria and sold to improve our economy, reduce unemployment and save our foreign exchange and finally, improve the lives of Nigerians.

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