# Microcontroller based Rehabilitation Stimulator

Purva Nanivadekar
Asst. Professor
Biomedical Department
Dwarkadas J Sanghvi College of Engineering

Shivali Kar
Asst. Professor
Electronics Department
Dwarkadas J Sanghvi College of Engineering

## ABSTRACT
A rehabilitation stimulator is a physiotherapeutic device. A patient is subjected to currents using electrodes and it brings the required results in the patient. The different current types are available and used for various functions. In the proposed system the currents are produced with the help of a microcontroller which makes it more accurate, compact and cost effective. The programming is done in assembly language using microcontroller 89C51. The prototype is implemented and user interface was provided by a matrix keyboard and LCD. Current can be subjected to the patient via surface electrodes. There are few contraindications where in the rehabilitation stimulator should be avoided.

## General Terms
Electrotherapy, Nerve muscle stimulator

## Keywords
Rehabilitation, Nerve muscle stimulator, microcontroller

## 1. INTRODUCTION

As the number of people suffering from pain, joint motion, dysfunction of neuromuscular system, weakness or tissue atrophy is increasing year by year it has become important for us to develop something using both physiological and technical knowledge which can give relief to these patients. Electrotherapy, employing low volt, low frequency impulse currents, has become an accepted practice in the physiotherapy departments. The effects of low volt currents help in management of diseases related to nerve and muscles. e.g. Treatment of paralysis with totally or partially degenerated muscles, for the treatment of pain, muscular spasm, peripheral circulatory disturbances etc. Rehabilitation stimulator is a physiotherapy device which is used for pain relief, treatment of paralysis, muscle re-education as well as for activation of muscles. Usually, two electrodes are connected from the machine to the patient’s skin. The electrodes are often placed on the affected area of pain or at a pressure point, creating closed circuit of electrical impulse that travels along nerve fibers. A current which varies sufficiently in magnitude can stimulate a motor nerve and so produce contraction of the muscles which it supplies, while in absence of a motor nerve the muscle fibers can be stimulated directly by a suitable current [1].

Generally four types of currents can be used for stimulation. They are Galvanic, Interrupted galvanic, Faradic and surged faradic. Galvanic currents are used in case of excessive sweating, iontophoresis. Interrupted galvanic is used in case of muscle activation from 0 to1. Faradic is used in case of muscle activation from 1 to 2and 2 to 3, also in cases of re-education of muscle action. Surged Faradic is used in case of edema.

In general physiology nerves carry messages from the brain to the muscles. They also carry messages from sensors back to the brain. They are the 'wires' of the body. Nerves are like an elongated bag of salty water. The outside of the nerve is positively charged. In other words it is polarized. That charge is lost when the top end of a nerve cell is stimulated. This is called depolarization. The wave of depolarization runs down the cell from the brain to the muscle. The nerve swells out near the muscle at the 'neuro-muscular junction'. The nerves cell releases a special chemical called Acetyl-choline into the gap between the nerve and the muscle. Muscles have a polarized membrane surrounding them that is very similar to nerves. There are special receptors built into this membrane. When Acetyl-chorine attaches to a receptor the membrane is depolarized. The wave of depolarization runs over the muscle fiber and causes it to contract. A neuromuscular junction (NMJ) is the synapse or junction of the axon terminal of a motor neuron with the motor end plate, the highly-excitable region of muscle fiber plasma membrane responsible for initiation of action potentials across the muscle's surface, ultimately causing the muscle to contract [2].

Stimulation of nerve impulse can be initiated by an electrical stimulus. To achieve this, varying current of adequate intensity must be applied. The plasma membrane of the nerve fiber forms a resistance which lies in series with the order tissues, so a potential difference is set up across it as the current flows. The surface of the membrane nearer to cathode becomes negative in relation to other surface. On the side of the nerve nearer to anode this increases the resting potential difference across the membrane, but on the side of the nerve nearer to cathode, the additional charges are of opposite polarity to those present on the resting membrane and so reduces the potential difference across it. If the potential difference falls below the level at which the membrane becomes permeable to sodium ions, these ions begin to enter the axon and initiate series of events so that a nerve impulse is initiated. A nerve stimulator supplies electrons to depolarize a nerve. The number of electrons supplied per stimulus equals the current. To make sure that the nerve is completely depolarized we keep winding up the stimulating current until the muscular response does not increase any more, and then we add another 10%. This is called the supra-maximal stimulus. At this point we assume that the nerve supplying the muscle is completely depolarized. As a result the muscle must be maximally stimulated by the nerve. The muscle contraction that results must also be maximal. (The contraction is also called a twitch). The muscle response to the stimulus is called a twitch. The amount or strength of movement is called the twitch height. (From the height of the trace on a recorder) To allow comparison of twitches it is essential that this current remains constant to ensure the nerve is always completely depolarized. [3]- [5] Fig.1 shows the generalized block diagram for stimulator.

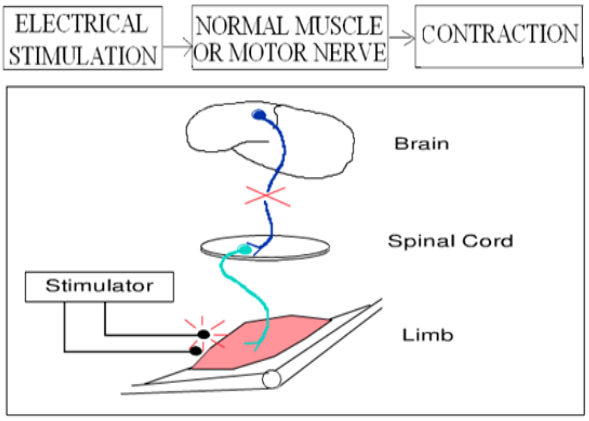



**Fig 1: General Principle of stimulator**

### Indications for the use of Rehabilitation Stimulator

#### *1. Facilitation of muscle contraction –*

When a patient is unable to produce a muscle contraction, or find it difficult to do so, electrical stimulation may be use in assisting voluntary contraction. Electrical stimulation of motor neurons should reduce the inhibition, so facilitating the transmission of voluntary impulses to the muscle and also inducing relaxation of its antagonists. When muscle contraction is inhibited by pain or any injury, for instance when active contraction of the quadriceps is impossible in rheumatoid arthritis of knee joint, electrical stimulation may be assistance in establishing voluntary contraction.

#### *2. Re-education of muscle-action -*

Inability to contract a muscle voluntarily may be result of prolonged disuse, as in the intrinsic foot muscle in a longstanding flat foot, or of incorrect use. In such case electric stimulation used to produce contractions and so help to restore the sense of movement. It will probably take longer time to establish a voluntary contraction but once satisfactory contraction can be performed electrical stimulation should be discontinued.

#### *3. Training a new muscle-action -*

After tendon transplantation or other reconstruction operations a muscle may be required to perform a different action from that which it previously carried out. Electrical stimulation is applied to muscle, so that new action is performed, and patient must concentrate on the movement and attempt to assist with voluntary contractions.

#### *4. Neurapraxia of a motor nerve -*

In this case impulses from the brain are unable to pass the site of the lesions to reach the muscles supplied by the affected nerve. Consequently voluntary power is reduced or lost. There is however, no degeneration of the nerve, so that if it is electrically stimulated below the site of the lesion, impulses pass to the muscles, causing them to contract. Recovery takes place without any marked changes in the muscle tissue.

#### *5. Severed motor nerve –*

When a nerve has been served, degeneration of the axons takes place and there is no longer a satisfactory response to stimuli of short duration, Degeneration takes several days, and for a few days after the injury a muscle contraction obtained by electrical stimulation.

#### *6. Improved venous and lymphatic drainage –*

Increased venous and lymphatic return is brought about by the pumping action of alternate muscle contraction and relaxation and of joint movement on the veins and lymphatic's. In this case appropriate electrical stimulation is used for muscle contraction.

#### *7. Improved venous and lymphatic drainage -*

Increased venous and lymphatic return is brought about by the pumping action of alternate muscle contraction and relaxation and of joint movement on the veins and lymphatic. Using an electric current muscle is stimulated.

## 2. REHABILITATION STIMULATOR

Rehabilitation muscle stimulator, also known as neuromuscular electrical stimulator, is used for the elicitation of muscle contraction with electric impulses. The impulses are generated by a device and delivered through electrodes on the skin in direct proximity to the muscles to be stimulated. The impulses mimic the action potential coming from the central nervous system, causing the muscles to contract. The electrodes are generally pads that adhere to the skin. Stimulator is both a form of electrotherapy and of muscle training.

### 2.1 Types of Current Used for Therapy

*2.1.1. Galvanic Current* – Fig.2 shows a galvanic current. It represents a constant electron flow from the negative to the positive electrode with no alterations (with constant polarity). In this treatment method the duration of current flow is long and continuous. Galvanic current creates an electric field over the treated area that theoretically, changes blood flow. When steady flow of direct current is passed through a tissue, its effect is primarily chemical. It causes the movement of ions and their collection at the skin areas lying immediately beneath the electrodes. Direct Galvanic current is mainly used for Ionization i.e. transference of ions of drugs into the tissues through the skin for pain relief. It is also used for stimulation of weak muscles and preliminary treatment of atonic paralysis. In general the intensity of current passed through the any part of the body does not exceed 0.3 to 0.5ma/sq cm. of electrode surface. The duration of treatment is 10-20 minutes.

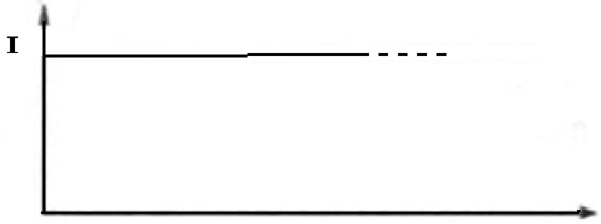
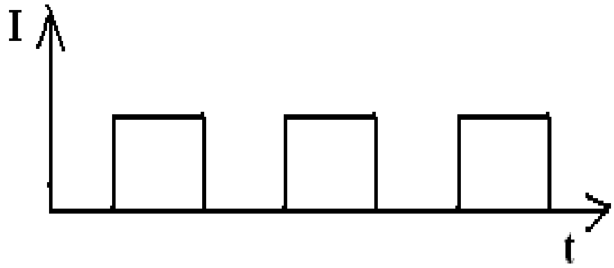
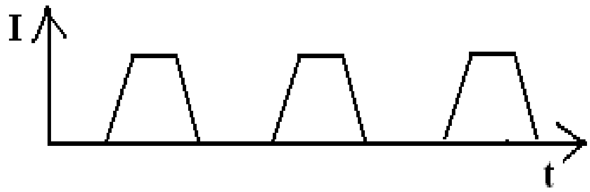



**Fig.2 Galvanic Current Waveform**

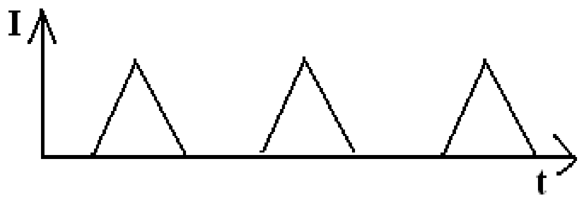
*2.1.2. Interrupted Galvanic* – In an interrupted current, pulses are series of ongoing square pulses. The duration and frequency of impulses can be adjusted; duration of 100 ms is being commonly used. It is often an advantage to increase this to 300 or 600ms. An impulse of about 100 ms duration requires a frequency of about 30 per minute. The interval between the impulses should never be of shorter duration than the impulses themselves and is usually appreciably longer. The rise and fall of intensity may be sudden (square impulses) or gradual (trapezoidal, triangular and saw-tooth impulses).Fig.3 shows the unidirectional, interrupted galvanic pulses.




(a)




(b)




(**c**)

**Fig. 3 (a) Square interrupted Galvanic Current waveform (b) Trapezoidal interrupted Galvanic Current waveform (a) Triangular interrupted Galvanic Current waveform**

*2.1.3. Faradic* – Faradic current is a sequence of pulses with defined shape and current intensity, as shown in fig. 4. The pulse duration is of 0.1-1 ms and frequency of 50-100 Hz. During such a waveform, the rise rate is rapid but not instantaneous, falling back rapidly to zero immediately after reaching the maximum i.e. spike. Faradic current acts upon muscle tissue and upon the motor nerves to produce muscle contraction. There is no ion transfer and consequently, no chemical effect. This may be used for the treatment of muscle weakness after lengthy immobilization and of tissue atrophy.

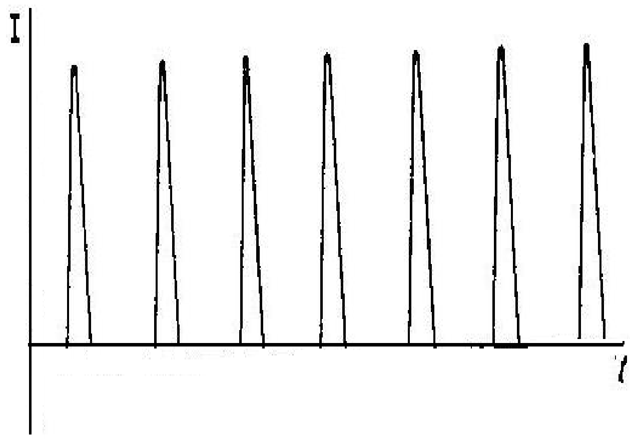



**Fig. 4 - Faradic Current Waveform**

*2.1.**4.** Surged Faradic*- Here peak current intensity applied to the patient increases and decreases rhythmically, and rate of increase and decrease of the peak amplitude is slow, the resulting shape of current waveform is called a surging current. It is possible to produce surges of various durations, frequencies and waveforms. The main field of application of the surge current is in treatment of functional paralysis. This type of current usually required for the treatment of spasm and pain. The response is as shown in fig.5

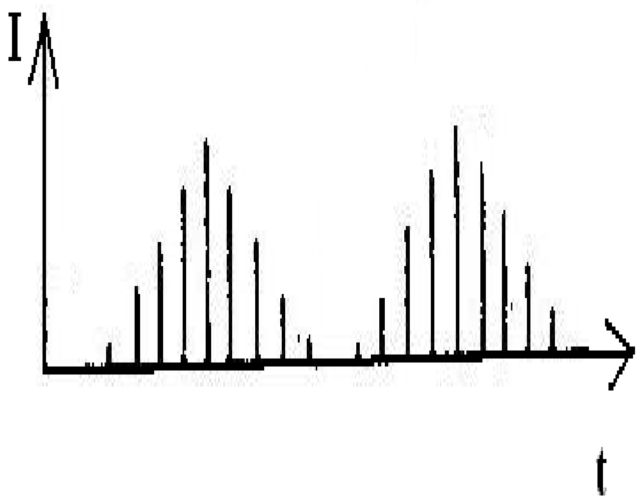



**Fig. 5 Surged Faradic Current Waveform**

## 2.2. Block Diagram

Fig.6 illustrates the basic block diagram of Microcontroller based rehabilitation stimulator. The basic components are the microcontroller, Keyboard Matrix, LCD Display, Digital to analog converter, transformer. Microcontroller is the main board which generates current waveforms. Using the keyboard, we can select type of current to be applied. Then we can select the frequency and duration of the pulses. LCD display will indicate the type of current as well as duration of the pulses. The digital output form microcontroller is converted to analog using appropriate DAC. The potentiometer is used to control the intensity of the current. This intensity varies from patient to patient. The current thus generated will be given to patient using appropriate electrodes.

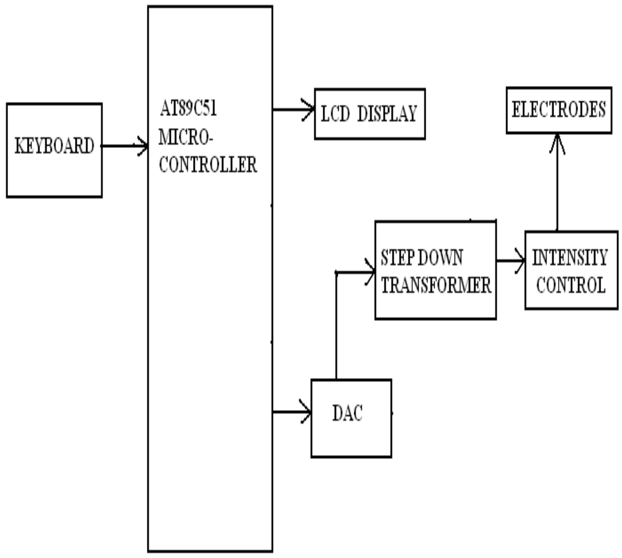



**Fig. 6 Block diagram of Rehabilitation Stimulator**

## 3. IMPLEMENTATION

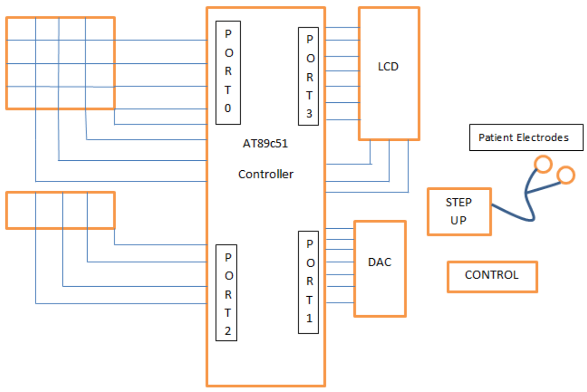



**Fig.7 Circuit Diagram: Rehabilitation Stimulator**

Fig.7 shows the circuit diagram for the prototype. The circuit for microcontroller based Rehabilitation Stimulator has been realized around microcontroller IC AT89C51, DAC 0808, Op-amp LM308, LCD display, Keyboards. The prototype generates galvanic, interrupted galvanic, trapezoidal, triangular, faradic, surged faradic current waveforms by a microcontroller AT89C51. Assembly language program was written to generate the said current waveforms as well as to display type of current waveform, pulse duration and its frequency reaching to the patient. Microcontroller's port P0.0 to P0.3 and P2.0 to P2.3 interfaced with 4*4 keyboard matrix, Port P0.4 to P0.7 interfaced with 1*4 keyboard matrix, Port P3.0 to P3.7 and P2.5 to P2.7 interfaced with LCD display, Port P1.0 to P1.7 interfaced with DAC 0808. With help of keypad select the appropriate current, it's pulse duration & frequency. Then the data is received by microcontroller. Accordingly microcontroller will execute the program. The output signal further given to intensity control circuit and then the moderate output is given to the patient via surface electrodes. Also LCD will display name of corresponding current with its pulse duration and frequency simultaneously. The voltage that goes to the patient is restricted to about 150V and the current that goes to the patient is kept below 100mA. Fig.8 is the implemented prototype.

**Fig.8 Microcontroller based Rehabilitation Stimulator**

## 4. POTENTIAL BENEFITS AND CONTRAINDICATIONS

The primary potential benefit of Neuromuscular Stimulator is the application of an electrical stimulus for use in muscle rehabilitation. A wide range of neurological and orthopedic diagnoses will benefit from the use of Rehabilitation Stimulator. Other benefits of stimulator include:

1. Lack of effects common with analgesics.
2. A possible reduction in need for other analgesics.
3. Feeling of improvement, as patients gain control over muscle action.
4. Moderate cost.

Rehabilitation stimulator generally considered safe, but improper application can cause problems. It should not used near wet areas. It should be avoided or used with caution by the following population:

1. People who had medical implants such as pacemakers or spinal cord stimulators, unless approved by a physician.
2. People with certain heart conditions. It may alter the heart rate of some people.
3. People with epilepsy or other seizure disorders. It may increase the risk of seizures in some cases, such as if the electrodes were to be placed on the scalp or face.
4. Women who are pregnant, unless strictly supervised by physician. Pregnant women are especially advised not to use stimulator over abdomen or pelvic region. The effect of stimulator on fetal health is unknown and has not been studied.

Additionally, Stimulator should not use in the following areas of the body:

1. Over the carotid sinus. This is a large blood vessel in the neck just below the jaw. Application of stimulator there could cause blood pressure to drop.
2. Over throat. Application of it there could cause laryngeal muscle to spasm.
3. On broken or damaged skin and over the eyes or mouth.

## CONCLUSIONS

Rehabilitation Stimulator uses electrical impulses to stimulate the nerve endings at or near the site of affected area and replacing it with a tingling or massage like sensation. It stimulates nerves, muscles and cells via surface skin by low electricity to make the brain produce endorphin naturally and then to reach the goal of relieving syndromes and stopping pain. There is at present abundant evidence that Rehabilitation Stimulator provides a highly efficient tool for the activation nerve-muscle without any side effects.

The development has given a considerable to the actual designing process has been carried out on the commercial basis. From the start of the project, it has helped to know about component selection, circuit implementation, PCB fabrication, chassis and front panel designing. The project development has created awareness about all the facets of the product designing.

As a conclusion, the project development has been much useful in the four years of bachelor's Degree of biomedical Engineering course as it helps in the various phase of an actual product designing.

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