PROJECT REPORT

On

DESIGN OF A MULTIFREQUENCY T.E.N.S UNIT FOR THERAPEUTIC PURPOSES

Submitted for partial fulfillment for the award of the degree

BACHELOR OF TECHNOLOGY

in

ELECTRONICS AND COMMUNICATION ENGINEERING

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(Deemed to be **University** *u/s 3 of UGC Act, 1956)*

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APRIL 2018

BONAFIDE CERTIFICATE

Certified that this project report titled **DESIGN OF A MULTIFREQUENY T.E.N.S UNIT FOR THERAPEUTIC PURPOSES** is the Bonafide work of **HARIRAM.K (RA1411004040074)** and **KARTHIK.S (RA1411004040105)** who carried out the project work under my supervision as a batch. Certified further, that to the best of my knowledge the work reported herein does not form any other project report on the basis of which a degree or award was conferred on an earlier occasion for this or any other candidate.

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ABSTRACT

The Transcutaneous Electrical Nerve Stimulation (TENS) unit utilizes electric impulses to stimulate nerves for therapeutic purposes. It applies an electric current signal at a particular frequencies to excite nerves, primarily to treat pain, based on its ability to modulate pulse width, frequency and intensity. The design of our T.E.N.S unit is going to be based on using integrated circuits to generate waves of optimum frequency (depending on the RC time) to two electrodes. Further, we are going to implement potentiometers into our circuit to modify the power output, and make the device portable enough to find their applications in several medical fields such as physiotherapy and dentistry. This project is going to focus on making the device as user friendly as possible, so as to enable domestic use without prescription.

CHAPTER 1
INTRODUCTION

The need for a T.E.N.S Unit is to have such a device that provides a drug-free and side-effect free method to treat patients facing different kinds of pain symptoms. The device designed in this paper will be able to provide a wide range of therapy applications due to its capacity to provide modifiable multiple frequencies. Further, it will also consist of two modes that will provide continuous and discontinuous/intermittent types of pulses depending on the intensity of therapy required, i.e. short term or long term.

Pain is an important concept of the nervous system in giving the body with an alert of potential or injury. Being a sensory and emotional experience, it is supported by psychological factors such as past experiences, beliefs about pain, fear or anxiety. The sensory receptors at the nerve endings pick up the pain that is induced due to injury. These nerves then transmit the pain to the brain through the spinal cord.. There are specialized receptors called Nociceptors, which are then conducted to the central nervous system.

Hundreds of clinical reports exist concerning the use of TENS for various types of conditions, such as low back pain (LBP), myofascial and arthritic pain, sympathetically mediated pain, bladder incontinence, neurogenic pain, visceral pain, and postsurgical pain. Because many of these studies were uncontrolled, there has been ongoing debate about the degree to which TENS is more effective than placebo in reducing pain.

A simple T.E.N.S Unit is shown in the figure.1. below.

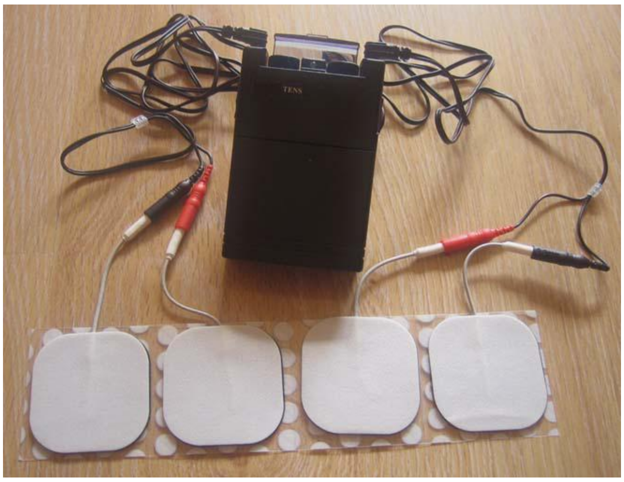

Figure 1. T.E.N.S Unit

1.1 OVERVIEW OF USING A T.E.N.S UNIT TO RELIEVE PAIN

The currently proposed mechanisms by which TENS produces neuromodulation include the following:

• Presynaptic inhibition in the dorsal horn of the spinal cord

• Endogenous pain control (via endorphins, enkephalins, and dynorphins)

• Direct inhibition of an abnormally excited nerve

• Restoration of afferent input

The results of laboratory studies suggest that electrical stimulation delivered by a TENS unit reduces pain through nociceptive inhibition at the presynaptic level in the dorsal horn, thus limiting its central transmission. The electrical stimuli on the skin preferentially activate low-threshold, myelinated nerve fibers. The afferent input from these fibers inhibits propagation of nociception carried in the small, unmyelinated C fibers by blocking transmission along these fibers to the target or T cells located in the substantia gelatinosa (laminae 2 and 3) of the dorsal horn.

Studies show marked increases in beta endorphin and met-enkephalin with low frequency TENS, with demonstrated reversal of the antinociceptive effects by naloxone.These effects have been postulated to be mediated through micro-opioid receptors. Research indicates, however, that high-frequency TENS analgesia is not reversed by naloxone, implicating a naloxone-resistant, dynorphin-binding receptor. A sample of cerebral spinal fluid in those subjects demonstrated increased levels of dynorphin A. The mechanism of the analgesia produced by TENS is explained by the gate-control theory proposed by Melzack and Wall in 1965. The gate usually is closed, inhibiting constant nociceptive transmission via C fibers from the periphery to the T cell. When painful peripheral stimulation occurs, however, the information carried by C fibers reaches the T cells and opens the gate, allowing pain transmission centrally to the thalamus and cortex, where it is interpreted as pain. The gate-control theory postulates a mechanism by which the gate is closed again, preventing further central transmission of the nociceptive information to the cortex. The proposed mechanism for closing the gate is inhibition of the C-fiber nociception by impulses in activated myelinated fibers. Figure.2 shows the concept of pain.

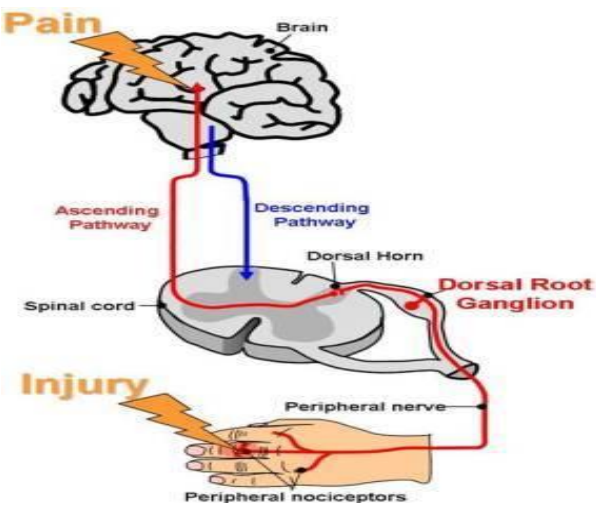

Figure 2. Concept of Pain

1.2 EXISTING SYSTEMS

A TENS unit provides electrical stimulation to the painful area using electrodes attached to the skin. Some scientists say that electrical signal can stop nerve sensation that sends the signals to the brain. These signals provide a kind of natural pain relieving substance or so to day endorphins. The TENS unit stops these signals to the brain, which means the patient can't feel pain he was experiencing.

The existing T.E.N.S Units designed with the concepts of either high or low frequency for its corresponding applications. For example, to relieve pain in a sensitive part, such as hands, would require electric impulses of low frequency, whereas, in the legs or places that has more muscle and bone structure would require the production of higher frequency impulses.

The features of some of the existing T.E.N.S Units researched for this paper are given in the following Table.1.:

Product	**Type of Pain**	**Benefits**	**Features**
Touch TENS	General Pain	Simple to use.	Preset functions.
Target TENS	General Pain	Traditional style.	Wide range of settings.
TENS 7000	General Pain	Powerful and effective.	Either low or high frequency modification.

Table.1. Features of recent existing T.E.N.S Units.

The construction of these T.E.N.S Units were analyzed, and it indicated that they work by providing continuous electric impulses using switching oscillators. It was identified that as much as they provide good quality treatment, they still had the following drawbacks.

- Most of them are application specific, meaning, they can be used to treat only a particular type of pain, or a few types of general pain.
- Usually comes in variants of either low or high frequency.
- They are temporary reliefs that can last anywhere between a few hours to a few days.
- Although they are simple to use, they still need to be used by a trained professional as prolonged exposure to continuous pulses can lead to muscle twitching.

To overcome these, this project provides the construction of a modified proposed system.

1.3 PROPOSED SYSTEM

Since medical professionals would require a device that can be used over a larger spectrum of applications, our research was focused on providing that along with long term effects. Our research indicates that with certain kinds of therapy, we can use intermittent pulses to provide pain relief effects over a longer term. Therefore, in our fabrication we use an intermittent oscillator along with the switching oscillator to provide two modes: continuous and short bursts of frequency impulses. The parameters of Output voltage, Pulse width, and Pulse rate are adjustable to provide a wider range of frequency for therapeutic treatments in a single device. Since intermittent pulses are used, muscle twitching does not occur, thereby leading to future scope for domestic use.

The block diagram of the modified proposed system is shown in Figure.3.

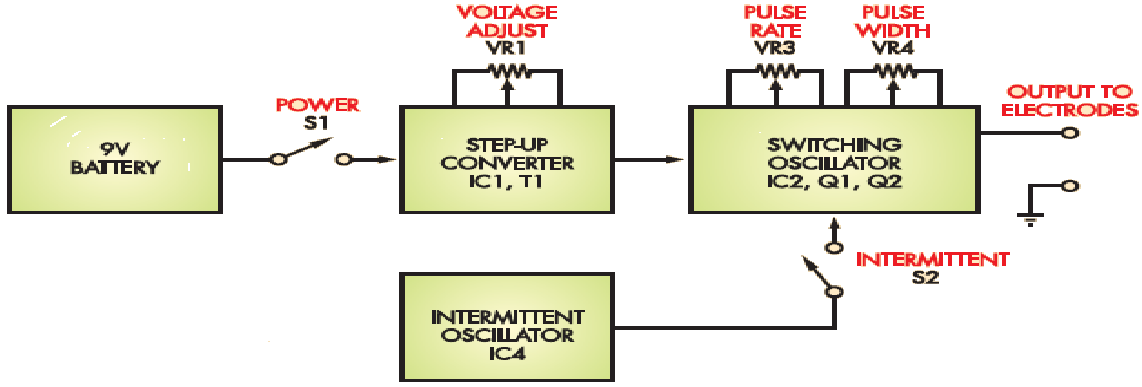

Figure 3: Block Diagram

The circuit was designed based on the concept of RC Time. The components used are:

- 9V input power source.
- A transformer that steps up the voltage from 12V to 80V.
- Integrated circuits 34063 for providing dual modes of continuous and intermittent oscillations, 7555 which acts as the switching oscillator and IR2155 which acts as the intermittent oscillator.
- Diodes 1N5819 and 1N4936 that act as the Schottky and Zener diode respectively.
- Oscillations created through the coupling of resistors and capacitors, i.e. RC time.
- A three terminal LM334Z adjustable current source.
- Two 6N60E MOSFETS that conduct the positive and negative half cycles of the oscillations generated.
- Potentiometers to modify the Output voltage, pulse width, and pulse rate.
- Electrodes that transfer the oscillated electric pulses to the human body.

The circuit diagram used is showed in Fig.4:

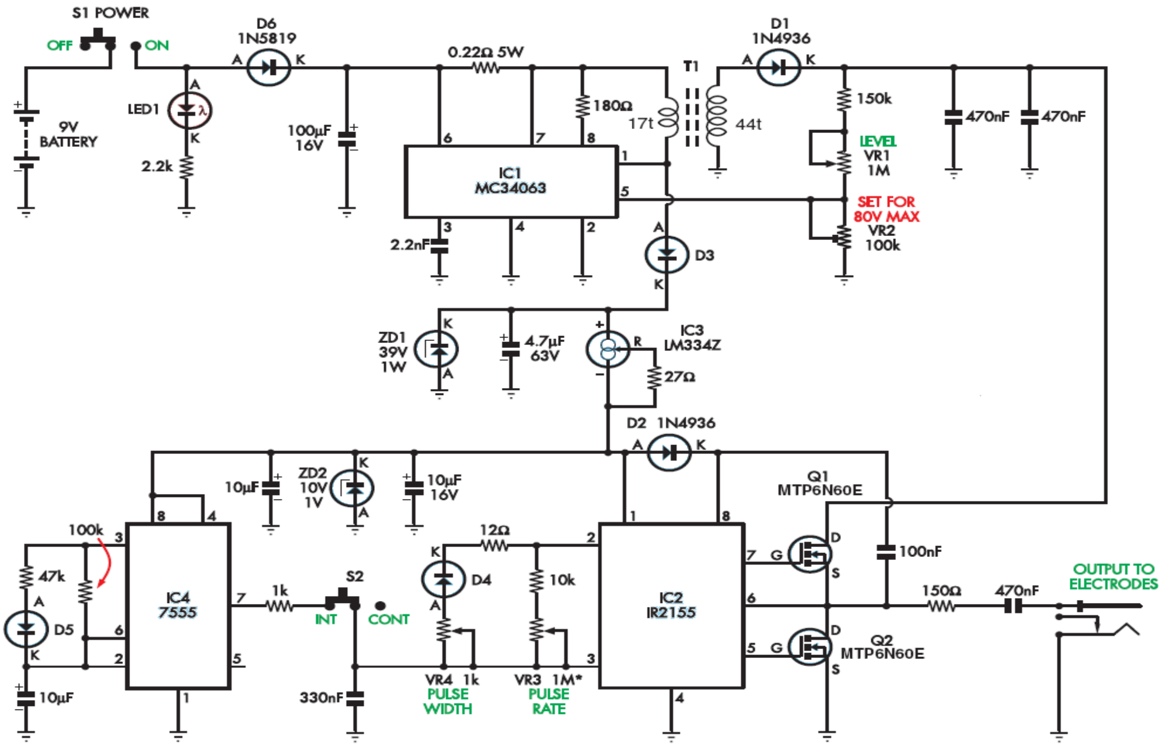

Figure.4. Circuit Diagram

CHAPTER 2
INTEGRATED CIRCUITS USED

2.1 INTRODUCTION TO IC7555

The IC7555 is a CMOS RC timers providing significantly improved performance over the standard SE/NE 555/556 and 355 timers, while at the same time being direct replacements for those devices in most applications. Improved parameters include low supply current, wide operating supply voltage range, low Threshold, Trigger and Reset currents, no crowbarring of the supply current during output transitions, higher frequency performance and no requirement to decouple Control Voltage for stable operation. Specifically, the ICM7555 is a stable controllers capable of producing accurate time delays or frequencies.

For astable operation as an oscillator, the free running frequency and the duty cycle are both accurately controlled by two external resistors and one capacitor. Unlike the regular bipolar SE/NE 555/556 devices, the Control Voltage terminal need not be decoupled with a capacitor. The circuits are triggered and reset on falling (negative) waveforms, and the output inverter can source or sink currents large enough to drive TTL loads, or provide minimal offsets to drive CMOS loads.

The IC7555 PIN diagram is shown in Figure.5.

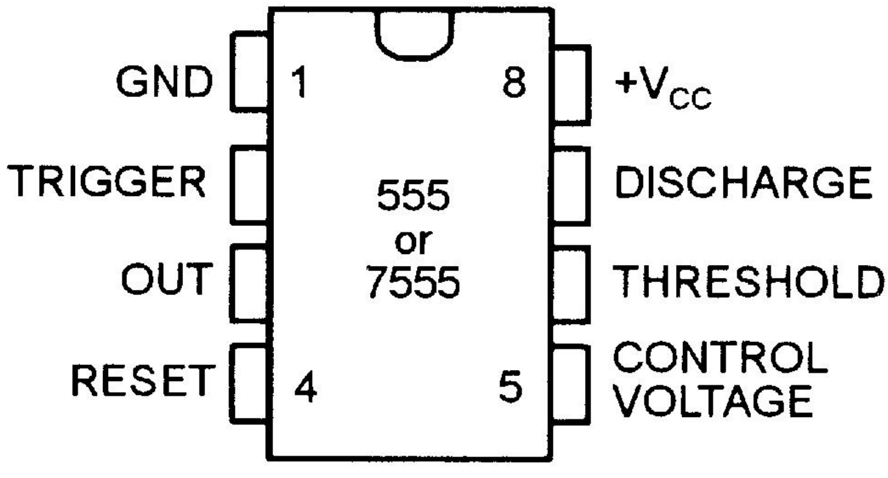

Figure 5 : IC7555 PIN DIAGRAM

2.2 INTRODUCTION TO IC2155

The IR2155 is a high voltage, high speed, self-oscillating power MOSFET and IGBT driver with both high and low side referenced output channels. Proprietary HVIC and latch immune CMOS technologies enable ruggedized monolithic construction. The front end features a programmable oscillator which is similar to the 555 timer. The output drivers feature a high pulse current buffer stage and an internal deadtime designed for minimum driver cross conduction. Propagation delays for the two channels are matched to simplify use in 50% duty cycle applications. The floating channel can be used to drive an N-channel power.

The PIN diagram of the IR2155 IC is shown in Figure.6.

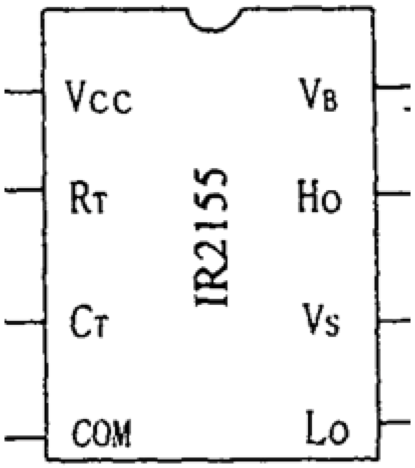

Figure.6. IR2155 PIN DIAGRAM

2.3 INTRODUCTION ICMC34063

The MC34063 Series is a monolithic control circuit containing the primary functions required for DC−to−DC converters. These devices consist of an internal temperature compensated reference, comparator, controlled duty cycle oscillator with an active current limit circuit, driver and high current output switch. This series was specifically designed to be incorporated in Step−Down and Step−Up and Voltage−Inverting applications with a minimum number of external components. Refer to Application Notes AN920A/D and AN954/D for additional design information.

Some of the features of this IC are:

• Operation from 3.0 V to 40 V Input

• Low Standby Current • Current Limiting

• Output Switch Current to 1.5 A • Output Voltage Adjustable

• Frequency Operation to 100 kHz • Precision 2% Reference

• NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC−Q100 Qualified and PPAP Capable

• These Devices are Pb−Free, Halogen Free/BFR Free and are RoHS Compliant.

MC34063 devices are easy-to-use ICs containing all the primary circuitry needed for building simple DC-DC converters. These devices primarily consist of an internal temperature-compensated reference, a comparator, an oscillator, a PWM controller with active current limiting, a driver, and a high-current output switch. Thus, the devices require minimal external components to build converters in the boost, buck, and inverting topologies.

The PIN Diagram of the MC34063 IC is shown in Figure.7.

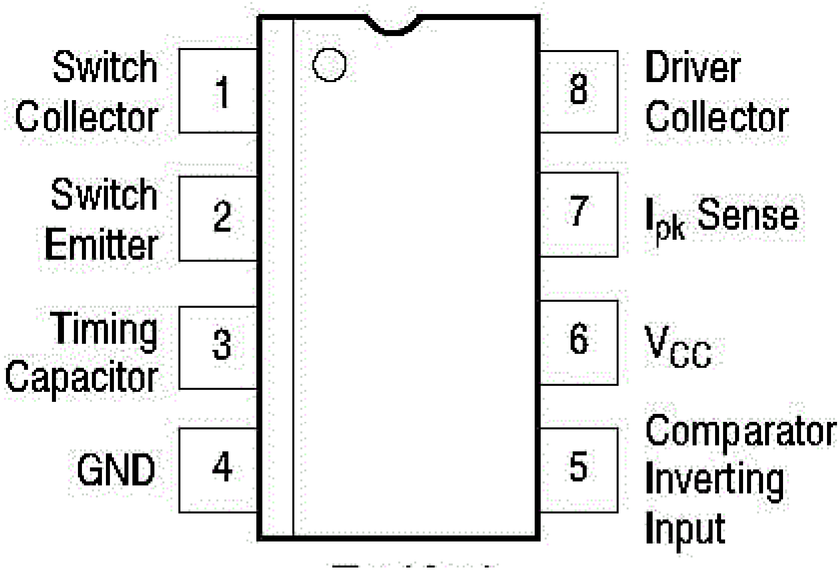

Figure.7. ICMC34063 PIN DIAGRAM

CHAPTER 3
COMPONENTS

3.1 9V BATTERY POWER SUPPLY

Our project requires an input of 9V. For this we used a regular 9V battery.
The battery has both terminals in a snap connector on one end. The smaller circular (male) terminal is positive, and the larger hexagonal or octagonal (female) terminal is the negative contact. The connectors on the battery are the same as on the connector itself; the smaller one connects to the larger one and vice versa.[2] The same snap-style connector is used on other battery types in the Power Pack (PP) series. Battery polarization is normally obvious since mechanical connection is usually only possible in one configuration. A problem with this style of connector is that it is very easy to connect two batteries together in a short circuit, which quickly discharges both batteries, generating heat and possibly a fire. Because of this hazard, 9-volt batteries should be kept in the original packaging until they are going to be used. An advantage is that several nine-volt batteries can be connected to each other in series to provide higher voltages

Figure 8: 9V BATTERY

3.2 STEP-UP TRANSFORMER

For voltage to be enough to implement the circuit we needed a transformer that steps up the voltage from 12V to 80V. This was achieved by using a toroidal coil with 26 gauge copper wires. It had 17 input turns and 44 output turns. With it, we can easily multiply or divide voltage and current in AC circuits. Indeed, the transformer has made long-distance transmission of electric power a practical reality, as AC voltage can be “stepped up” and current “stepped down” for reduced wire resistance power losses along power lines connecting generating stations with loads. At either end (both the generator and at the loads), voltage levels are reduced by transformers for safer operation and less expensive equipment.

The toroidal coil used in our circuit is shown in Figure.9.

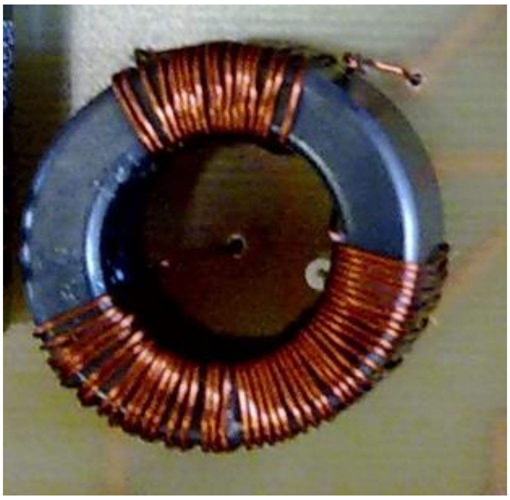

Figure.9. Toroidal Coil

3.3 DIODES

The project required diodes 1N5819 and 1N4936 that act as the Schottky and Zener diode respectively.

3.3.1. 1N5819 SCHOTTKY DIODE

The Schottky Rectifier employs the Schottky Barrier principle in a large area metal-to-silicon power diode. The Schottky Rectifier¿s state-of-the-art geometry features chrome barrier metal, epitaxial construction with oxide passivation and metal overlap contact. It is ideally suited for use as rectifiers in low-voltage, high-frequency inverters, free wheeling diodes and polarity protection diodes.

The 1n5819 diode used is shown in the Figure.10. below.

Figure.10. 1N5819 Diode

3.3.2 1N4936 DIODE

Axial−lead, fast−recovery rectifiers are designed for special applications such as DC power supplies, inverters, converters, ultrasonic systems, choppers, low RF interference and free wheeling diodes. A complete line of fast recovery rectifiers having typical recovery time of 150 nanoseconds providing high efficiency at frequencies to 250 kHz.

Features of this diode are:

• Shipped in Plastic Bags; 1,000 per Bag

• Available Tape and Reeled; 5,000 per Reel, by Adding a “RL” Suffix to the Part Number

• These are Pb−Free Devices*

Mechanical Characteristics:

• Case: Epoxy, Molded • Weight: 0.4 Gram (Approximately)

• Finish: All External Surfaces Corrosion Resistant and Terminal Leads are Readily Solderable

• Lead Temperature for Soldering Purposes: 260°C Max. for 10 Seconds

• Polarity: Cathode Indicated by Polarity Band

An 1n4936 diode is shown in the Figure.11.

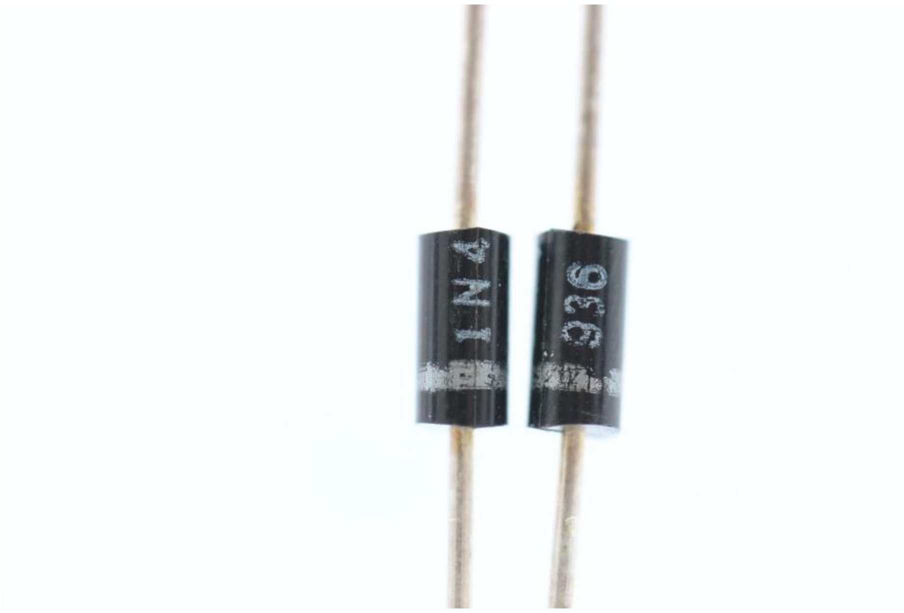

Figure.11. 1N4936 DIODES

3.4. RESISTORS AND CAPACITORS

Since the device works on the principle of RC Time, it is important to choose resistors and capacitors of appropriate value.

The resistors chosen were of value (in ohms):

2.2k, 0.22, 180, 150, 150k, 47k, 100k, 1k, 10k, 12.

Variable resistors of 1k, 100k, and 1M were chosen to modify the parameters of output voltage, pulse rate, and pulse width.

The capacitors chosen were of value (in Farads):

100u, 2.2n, 470n, 10u, 330n, 100n.

3.5. LM334

The LM334 is a 3-terminal adjustable true temperature sensors with ensured initial current sources featuring 10,000:1 range in operating accuracy of ±3°C and ±6°C, respectively. These current, excellent current regulation and a wide devices are ideal in remote sense applications dynamic voltage range of 1V to 40V. Current is because series resistance in long wire runs does not established with one external resistor and no other affect accuracy. In addition, only 2 wires are required. Initial current accuracy is ±3%.

The LM334 used in our circuit is shown in Figure.12.

Figure 12. LM334

3.6. MTP6N60E MOSFETS

This high voltage MOSFET uses an advanced termination scheme to provide enhanced voltage−blocking capability without degrading performance over time. In addition, this advanced MOSFET is designed to withstand high energy in the avalanche and commutation modes. The new energy efficient design also offers a drain−to−source diode with a fast recovery time. Designed for high voltage, high speed switching applications in power supplies, converters and PWM motor controls, these devices are particularly well suited for bridge circuits where diode speed and commutating safe operating areas are critical and offer additional safety margin against unexpected voltage transients.

The features are:

• Robust High Voltage Termination

• Avalanche Energy Specified

• Source−to−Drain Diode Recovery Time Comparable to a Discrete
Fast Recovery Diode

• Diode is Characterized for Use in Bridge Circuits

• IDSS and VDS(on) Specified at Elevated Temperature

There are two MOSFETS used in our circuit and the device used is shown in Figure.13.

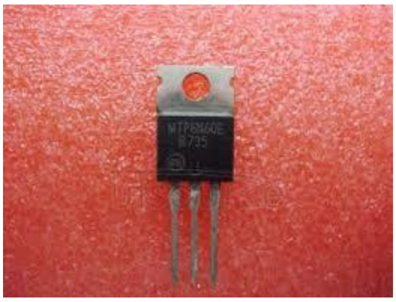

Figure.13. MTP6N60E MOSFET

CHAPTER 4
WORKING CONCEPT

4.1 PROJECT DESIGN

The circuit is designed in such a way to provide the following features:

There are two different modes:

- Continuous mode where a switching oscillator provides continuous pulses.
- Intermittent mode where an intermittent oscillator provides short bursts of pulses.

Usually the continuous mode is used but for long term treatment intermittent mode is used as research indicates the intermittent short bursts are more effective.

The device is adjustable and we can control three variables:

- Output voltage.
- Width of the pulses.
- Pulse rate.

Therefore, by controlling the parameters of pulse width and pulse rate, we can make the device work over a multiple range of frequency for a wide range of applications.

4.2 SWITCHING OSCILLATOR

The IC7555 acts as the switching oscillator. It produces a continuous repetitive output signal, such as a sine wave. The circuit consists of a feedback loop containing a switching device (in this case the timer IC) and a negative resistance device like a diode, that repetitively charges a capacitor or inductor through a resistance until it reaches a threshold level, then discharges it again. The period of the oscillator depends on the time constant of the capacitor circuit. The active device switches abruptly between charging and discharging modes, and thus produces a discontinuously changing repetitive waveform. This contrasts with the other type of electronic oscillator, the harmonic or linear oscillator, which uses an amplifier with feedback to excite resonant oscillations in a resonator, producing a sine wave.

A continuously produced switching oscillation wave is shown in Figure.14.

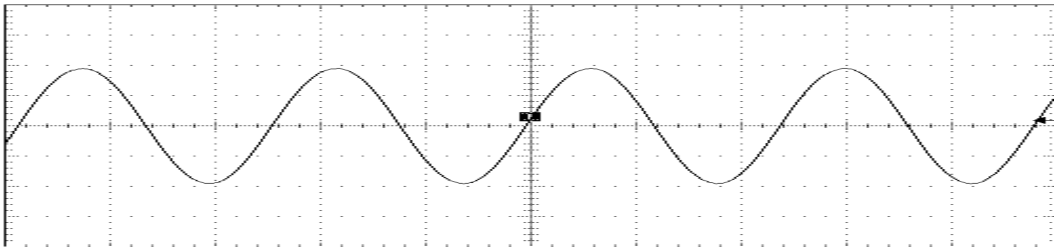

Figure.14. Continuous Sinusoidal oscillations

4.3. INTERMITTENT OSCILLATOR

The IR2155 IC along with the MOSFETS act as the intermittent oscillator. The intermittent oscillations are produced when the oscillations generated are blocked for a particular period of time and then restored after an irregular interval. The short bursts produced are of full high voltage during the oscillation period, and of a particular value of duty cycle (typically 24% for this device) and then goes to a value of zero afterward.

A duty cycle is the fraction of one period in which a signal or system is active. Duty cycle is commonly expressed as a percentage or a ratio. A period is the time it takes for a signal to complete an on-and-off cycle.

An intermittent pulse oscillation is shown in Figure.15.

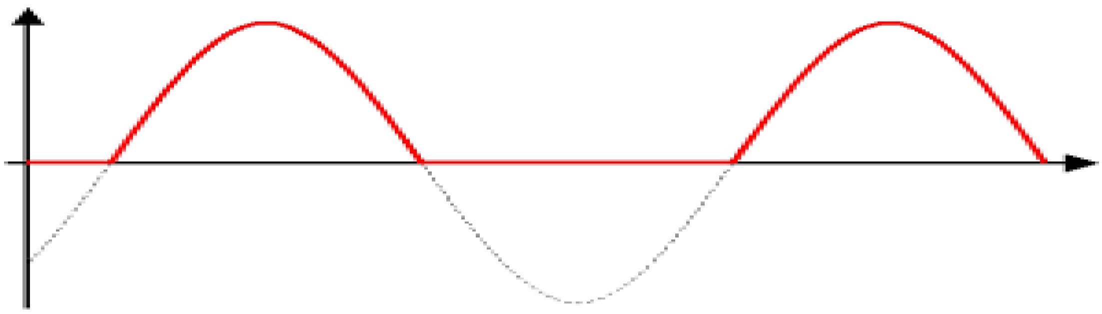

Figure.15. Intermittent Oscillations

4.4 OUTPUTS

The anticipated outputs for the designed circuit were:

Continuous Mode:

Output Voltage: Adjustable from 12V to 80V.

Pulse Rate: Adjustable from 4.6Hz to 410Hz.

Pulse Width: Adjustable between 70 and 320 µs.

Intermittent Mode :

Duty cycle: 24% at 1.2Hz

4.5 ELECTRODE PLACEMENT

In this device there are only two electrodes, so we think it will be a good idea to double the electrodes to cover more muscles. The electrodes are made of a light sponge like substance with an adhesive on the other end. They end on a 2mm female pin that can be connected to a male pin port and connected to the circuit to provide the necessary voltage and frequency outputs.

These electrodes can be used to treat a variety of pain symptoms in the body. This is done by placing the electrodes at the nerve endings that connect the muscle facing pain and providing the appropriate frequency of pulses, at the necessary mode of operation.

The different types of parts that can be treated are given by the following Figure.16.:

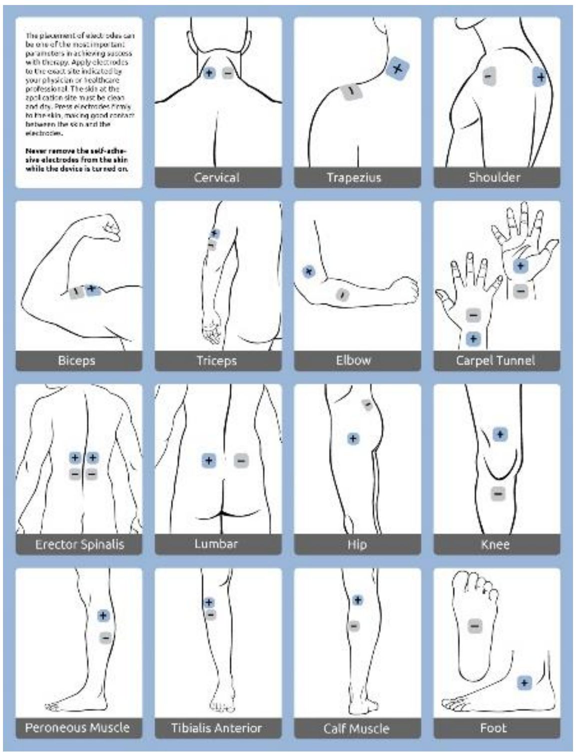

Figure. 16. Electrode placement chart

CHAPTER 5
SIMULATION AND IMPLEMENTATION

5.1 SOFTWARE SIMULATION

The circuit was simulated in part over multiple different software including PSPICE, Proteus, and Tektronix.

A wide array of devices and tools were available in these different types of software and the overall design of the circuit diagram was created using these services. The steps involved were to create the schematic first, and then designing it completely and running it to obtain the corresponding outputs.

The circuits designed in these software were done so with an objective to acquire continuous and intermittent outputs and the steps were all performed carefully.

5.1.1. CIRCUIT SCHEMATIC

From the designed circuit diagram on paper, the first step was to design the circuit schematic. All the components were assembled and then connected with wires.
Overlaps and nodes were made sure to be corrected and the entire circuit schematic was then set up for output simulation.
The circuit schematic designed is shown in the Figure.17.

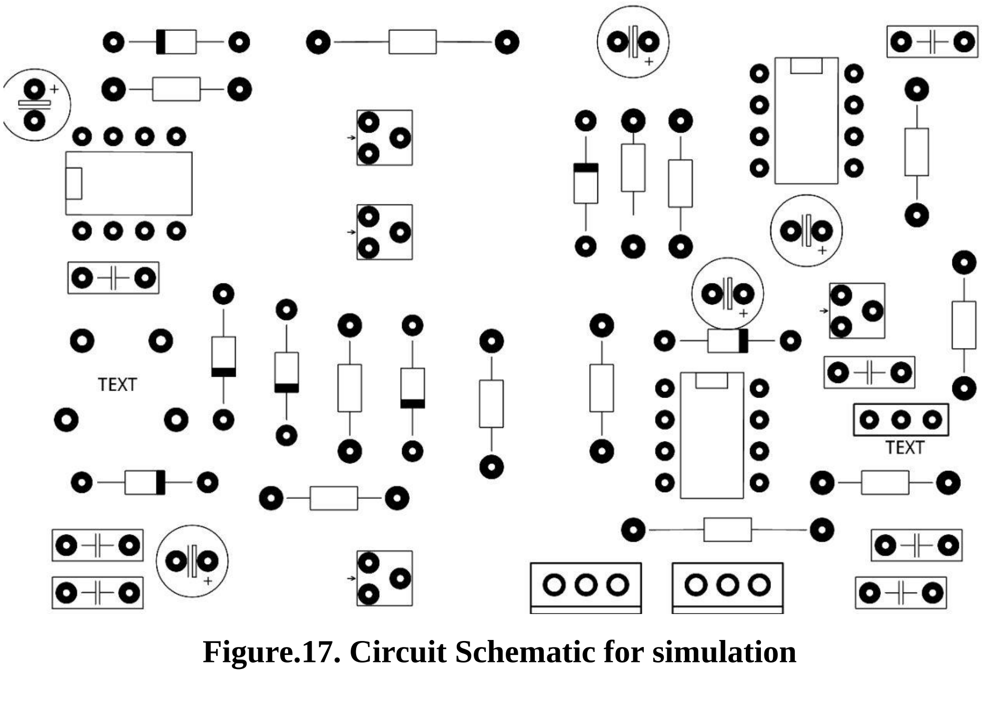

Figure.17. Circuit Schematic for simulation

5.1.2. RESULTS

The simulation yielded the results of two kinds. The continuous pulse results were of voltage 2V and 40Hz frequency, and the intermittent pulses were of 9.6Hz at 24% Duty cycle.

The continuous and intermittent results produced are shown in Figure.18. and Figure.19.

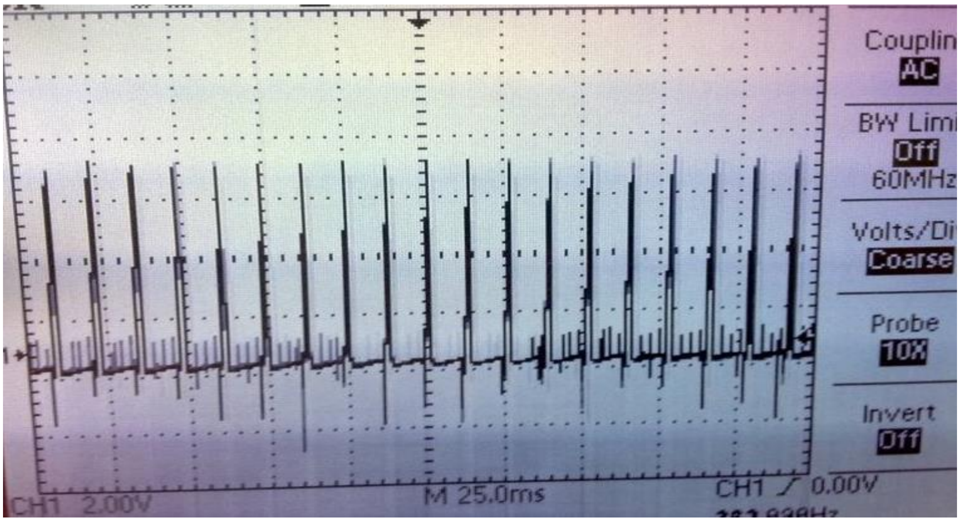

Figure.18. Continuous pulse simulation result.

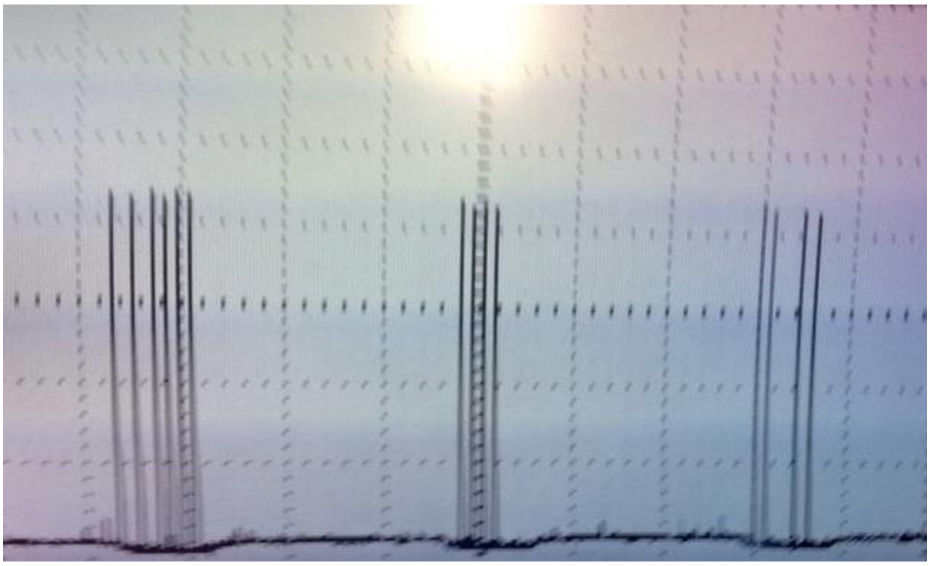

Figure.19. Intermittent pulse simulation result.

5.2 BREADBOARD IMPLEMENTATION

The software simulation motivated this project to be implemented on a breadboard. The first step was to make components required assembled and the input of 9V was supplied to the board. Then the second step was to connect the output points to the cathode ray oscilloscope and observe the outputs.

The circuit implementation is done in a way where all the required connections from the circuit diagram are made and then the input power supply is given. The working of the circuit is that an input of 9V is given to a step up transformer. The ICMC34063 decides the mode of operation and switches between them depending on the position of the switch. The IC7555 acts as the switching oscillator and the IC2155 acts as the intermittent oscillator as mentioned earlier.

The circuit implemented is shown in Figure.20 and the results obtained is shown in Figure.21. The breadboard implementation was observed with 8V and 60Hz continuous pulses and 14.4Hz intermittent pulses.

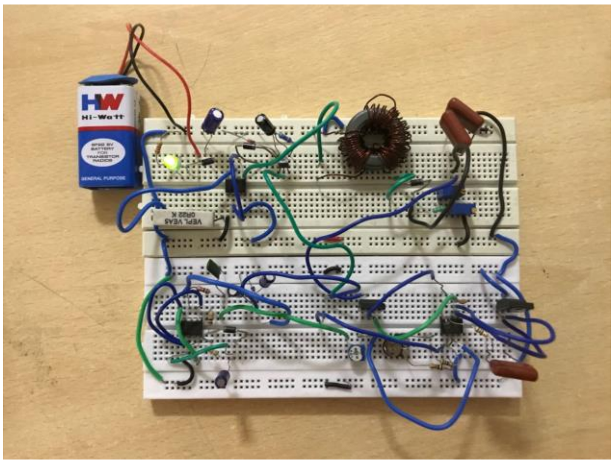

Figure.20. Breadboard Implementation of the circuit.

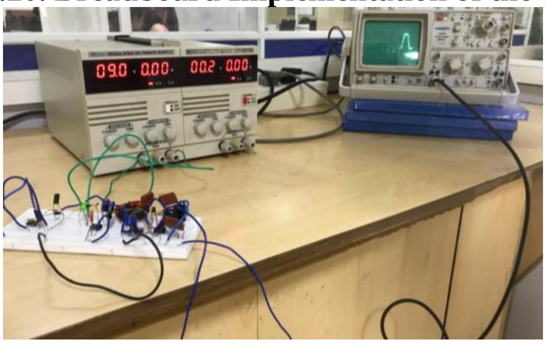

Figure.21. Implementation Results

CHAPTER 6
PCB IMPLEMENTATION OF DEVICE

6.1. ORCAD TRACK LAYOUT

The first step involved was to design the track layout to be printed on the board. This was done using OrCAD PCB Design tool. The circuit is first laid out and then the nodes are given as pins which are then interconnected using a track tool based on the circuit diagram.

The track layout designed using OrCAD is shown in Figure.22.

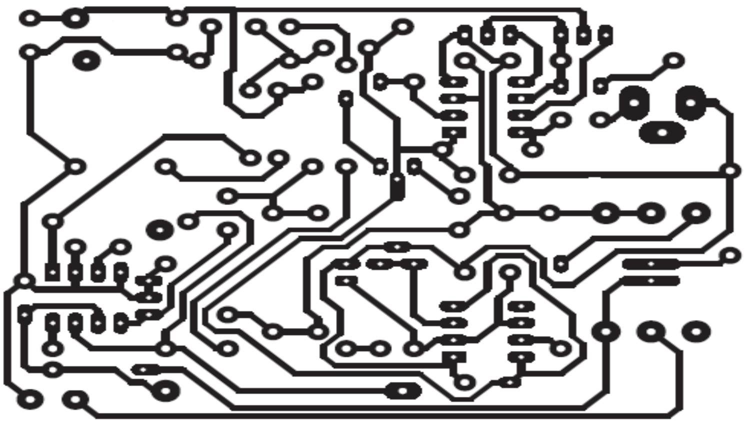

Figure.22. OrCAD PCB Track Layout

6.2. EXPRESS PCB SCHEMATIC

The track designed is then transferred as .pcb file to ExpressPCB software tool where the components can be placed to check the desired board size. By doing so, the drilling process would be simpler as the whole width and the exact size can be determined. The ExpressPCB schematic designed is shown in Figure.23.

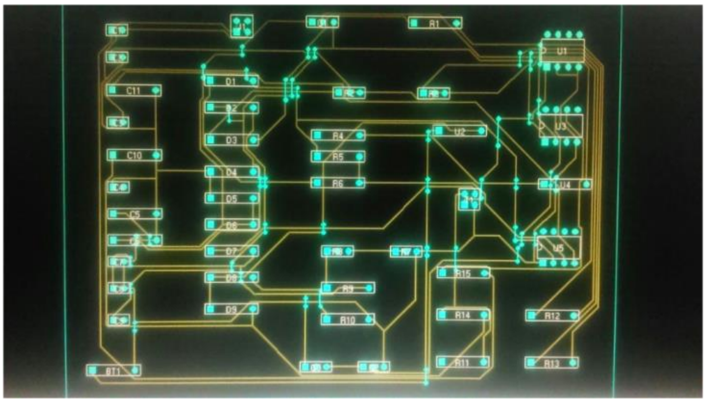

Figure 23. Express PCB Schematic

6.3. PCB CIRCUIT

The final implementation of the PCB design involved soldering the components onto the board and connecting the output electrodes onto the leads.

The PCB implemented T.E.N.S unit is shown in Figure.24.

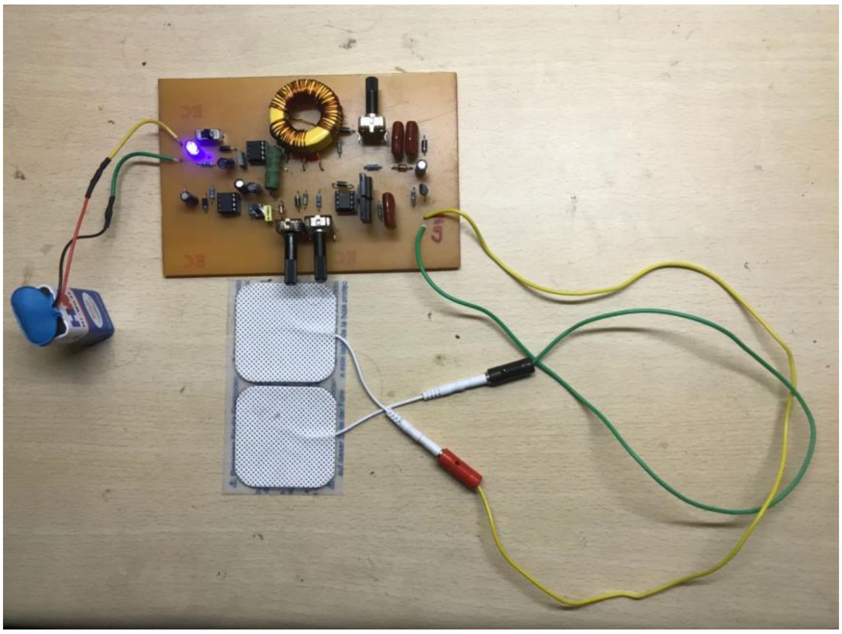

Figure 24. PCB implementation of the final T.E.N.S Unit

6.4. RESULTS AND FUTURE SCOPE

The results of the device was that it can be used to relieve pain and provide therapy over a wide range of frequencies. This can also be connected to a therapeutic ultrasound for more applications. A therapeutic ultrasound is shown in Figure.25.

Figure.25. Therapeutic Ultrasound

CHAPTER 7
CONCLUSION

This project therefore provides the full construction procedure of a medical device that provides therapy for acute and chronic pain. By studying the electrophysiological parameters, and then creating the design stages of the circuit, we have enable in modifying the parameters of the output. All the studies from paper was applied to the practical work and through all stages of the challenges presented were solved as applied the designed circuit onto a printed circuit board, so as to acquire the expected results. Finally, we tested the outcome of the circuit by applying the electrodes directly onto the human body.

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