Design of Therapeutic Ultrasound System for Muscles Pain Treatment

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Abstract

The most common causes of muscle pain are tension, stress, overuse and minor injuries. This type of pain is usually localized, affecting just a few muscles or a small part of your body.

Patients who suffer from muscle pain have previously been subjected to primitive treatment methods ,However, the pain is back after a period of treatment, The most important problem is that many patient are allergic to certain drugs that are given to relieve pain, while others are suffering from allergic to treatment methods Used.

Pain treatment with ultrasound facilitatesthe doctor treatment and reduces the time spent in it, solve, the problem of return the pain after a period of time, and it is easy to use and safety at the same time , which helps easy movement without pain.

In this project, a therapeutic ultrasound system designed to treat muscle pain.This system depend on ultrasound waves with a specific and appropriate frequency on the area of pain, which is increasing the temperature in the region of muscle pain. Hence increasing the activity of blood circulation as a result of the expansion of the diameter of blood vessels so increases the blood flow through it , and thus lead to increased muscle activity, and alleviate the pain. The technology can be used in medical centers, in physiotherapy centers, or in a hospitals.

الملخص

الأسبابالأكثرشيوعالآلامالعضلاتهيالتوتر،والإجهاد،والإفراطفيالاستخداموالإصاباتالطفيفة.
وعادةمايكونهذاالنوعمنالألمموضعيا،ممايؤثرعلىعددقليلمنالعضلاتأوجزءصغيرمنالجسد .

المرضى الذين يعانون من آلام في العضلات سبق أن تعرضوا لطرق العلاج البدائي ، ومع ذلك فإن الألم يعود بعد فترة من العلاج والمشكلة الأكثر أهمية هو أن العديد من المرضى لديهم حساسية من بعض الأدوية التي تعطى لتخفيف الألم في حين أن البعض الآخر الذين يعانون من الحساسية لطرق العلاج المستخدمة.

علاجالألممعالموجاتفوقالصوتيةيسهلعلاجالطبيبويقللمنالوقتالذييقضيهفيذلك،حلمشكلةعودةالألمبعدفترةمنالزمنو أنهمنالسهلللاستخداموالسلامةفينفسالوقتممايساعدعلىسهولةالحركةدونألم .

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Chapter one

Introduction

1.1 Overview.

1.2 Project Idea Description.

1.3 Project Motivation.

1.4 Project Objectives.

1.5 Literature Review and Related Work.

1.6 Economical Study.

1.7 Schedule Time.

Chapter one

Introduction

1.1 Overview

Muscles diseases is a worldwide disease which is largely extended in the last time . the main problem that relates with patients, is the long duration of the therapy required for pain treatment, and the pain will be return after a period of time , unfortunately the most common methods to treatment is Cry therapy, by using ice (lumps or cubes) or cold liquids (bags or compresses) or cold water directly on the areas of the body or by using cold room and air, these traditional methods involves a lot of drawbacks are not recommended in the treatment of certain conditions like using it with a patients who suffer from Reynaud syndrome, sensitivity to cold, under the influence of anesthesia hypertension and Cardiovascular diseases or in the case modern wounds.

1.2 Project idea description

In this project a therapeutic US system will be designed and implemental , this system has the ability to produce ultrasonic waves on a sites of muscles pain with specific frequency and the duration of treatment ,depending on a pain site depth. This wave causing a heating on this site, and expansion in the diameter of blood vessels , so that the blood circulation will be activated in the pain zone .

1.3 Project Motivation

Several people suffering from muscular pain, different traditional techniques used to treat it in hospitals and it take a long time. Furthermore , in most cases the pain returns after a period of treatment. The idea of this project is to design a system that can aid those patients to find a cheap and safe technique to solve this problem and saves patients time ,It can be used at home instead of going to hospitals.

1.4 Project objectives

The main objectives of this project can be summarized as follow :

- ❖ Design and implementation of US system as therapy.
- ❖ Help patients suffering from muscle inflammation or muscle convulsion or lack muscle activity.
- ❖ Increase muscle activity and reduce patient injury to muscular dystrophy.
- ❖ Activation the muscle and facilitates movement and relieve the pain.

1.5 Literature review and related work

Study comes to accomplish a lot of previous studies that include different therapy techniques a muscle pain. Treatment physical therapy has used many of the techniques to treat muscle diseases or develop vital or motion functions, and stop pain. These techniques are the product of human knowledge through the ages, example of previous techniques are mentioned below.

- ❖ Cryotherapy therapy, this treatment is very old and common and the temperature of the skin during the treatment to 10 C, used by the Chinese about 3,500 years ago, by using ice (lumps or cubes) or cold liquids (bags or compresses) or cold water directly on the areas of the body, Cases where cooling therapy when the patient is suffering from psychological fear from snow , heats problem , nerve injury or lack of sensitive.

- ❖ Water therapy was using for therapeutic purposes and this method contains several topics and extends to the use of steam rooms and pools to be used in the process of rehabilitation of patients with the motion and nervous system, The swimming pools used for treatment have a special design that allows them to play this role. The main advantage is the temperature, which is 35 degrees Celsius, which makes the patient completely relax and reduce the pain and promote blood circulation, but the Contraindication of using hydrotherapy : acute inflammation, body's temperature raising., heart disease , hypertension ,Vascular diseases., kidney Disease, Bleeding or cancer.

- Thermal therapy can be used in the home by using warm compresses, which are available today, such as warm compresses, warm towels, gel bags, Contraindications using of thermal therapy when Loss of sense, Burn, Circulatory problems, Acute phases of infection, Deep venous thrombosis, Cancer.
- Short Wave Therapy (Microwave diathermy),an electromagnetic waves used to treat muscle pain along the wavelength between infrared and short wave therapeutic. The generated heat is used to give the patient comfort, we cant use with the patient who is suffering from cancer .

- Massage is a type of natural therapy. It is one of the essentials of ancient Chinese medicine and has shown its benefits as an effective treatment to reduce stress, body pain and muscle tension. Muscle covers many vital organs in the body and forms a major part of its formation. For muscles include all body organs, it cannot be used in the case of bleeding of blood, Burn injury, Stroke, Fracture.

1.6 Economical Study

This section lists the estimated overall cost of the project components that will be used in the design and implementation of the system. Table 1.1 contains the main required hardware components of the project design, and it's cost.

Table 1.1: Estimated Component Cost.

Components	**Costs (JD)**
Inverting amplifier	2
Transisitors,resistance,capacitor and other component	30
Power supply	15
Transformer	10
Copper plate	7
Transducer	120
Total	184

1.7 Schedule Time

In this section a time plan is mode for the predictive project tasks due to the time zone of both coming semesters, this time plan shown in the table 1.2.

Table 1.2 : Timing Schedule of the First Semester.

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Identification of Project Idea															
Literature Review															
Data collection															
Design															
Documentation															
Prepare the Presentation															

Table 1.3 : Timing Schedule of the Second Semester.

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Full Designing	■	■	■	■											
Purchasing the Components				■	■	■	■	■							
System Implementation						■	■	■	■	■	■	■			
System Analysis									■	■	■	■			
Documentation											■	■	■	■	

Chapter Two

Anatomy and Physiology

2.1 The Definition of Muscles

2.2 Functions of the Muscular System

2.3 Types of Muscle

2.3.1 Skeletal Muscle

2.3.2 Smooth Muscle

2.3.3 Cardiac Muscle

2.4 Muscle Aches

2.4.1 Muscle spasm

2.4.2 Muscular dystrophy

2.4.3 Muscle strains

Chapter Two

Anatomy and Physiology

2.1 The Definition of Muscles

Muscle is a fibrous tissue that is contraction and extroversion in the human body, the part responsible for the movement of the organism? The human body consists of about six hundred and fifty muscles, which make up about half the weight of the human body as show in figure 2.1[1] .

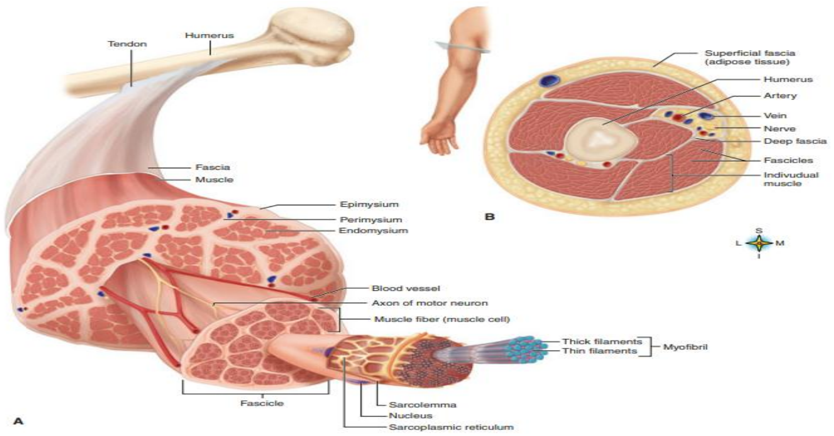

Figure 2.1 : Structure of muscles organ[1].

Muscles cells contain protein filaments of actin and myosin that slide past one another, producing a contraction that changes both the length and the shape of the cell. Muscles function to produce force and motion. They are primarily responsible for maintaining and changing posture, locomotion, as well as movement of internal organs, such as the contraction of the heart and the movement of food through the digestive system[1].

Muscles are predominantly powered by the oxidation of fats and carbohydrates, but anaerobic chemical reactions are also used, particularly by fast twitch fibers. These chemical reactions produce adenosine triphosphate (ATP) molecules that are used to power the movement of the myosin heads. The term muscle is derived from the Latin muscles meaning, "little mouse" perhaps because of the shape of certain muscles or because contracting muscles look like mice moving under the skin[1].

2.2 Functions of the Muscular System

1. Locomotion.

2. Vasoconstriction and vasodilatation- constriction and dilation of blood vessel Walls are the results of smooth muscle contraction.

3. Peristalsis – wavelike motion along the digestive tract is produced by the Smooth muscle.

4. Cardiac motion.

5. Posture maintenance- contraction of skeletal muscles maintains body posture and muscle tone.

6. Heat generation – about 75% of ATP energy used in muscle contraction is released as heat[1].

2.3 Types of Muscle

There are three types of muscle found in the human body:

- Skeletal Muscle.
- Smooth Muscle.
- Cardiac Muscle (heart muscle) as shows in figure 2.2 [2] .

Figure 2.2 : types of muscles[2] .

2.3.1 Skeletal Muscle

Skeletal muscle, attached to bones, is responsible for skeletal movements. The peripheral portion of the central nervous system (CNS) controls the skeletal muscles. Thus, these muscles are under conscious, or voluntary, control. The basic unit is the muscle fiber with many nuclei. These muscle fibers are striated (having transverse streaks) and each acts independently of neighboring muscle fibers.

The structure of skeletal muscle, a whole skeletal muscle is considered an organ of the muscular system. Each organ or muscle consists of skeletal muscle tissue, connective tissue, nerve tissue, and blood or vascular tissue.

Skeletal muscles vary considerably in size, shape, and arrangement of fibers. They range from extremely tiny strands such as the stipendium muscle of the middle ear to shape and some narrow. In some muscles, the fibers are parallel to the long axis of the muscle; in some, they converge to a narrow attachment; and in some they are oblique.

Each skeletal muscle fiber is a single cylindrical muscle cell. An individual skeletal muscle may be made up of hundreds, or even thousands, of muscle fibers bundled together and wrapped in a connective tissue covering. A connective tissue sheath called the perimysium surrounds each muscle. Fascia, connective tissue outside the perimysium, surrounds and separates the muscles.

Skeletal muscle cells (fibers), like other body cells, are soft and fragile. The connective tissue covering furnish support and protection for the delicate cells and allow them to withstand the forces of contraction..

Skeletal muscles have an abundant supply of blood vessels and nerves. This is directly related to the primary function of skeletal muscle, contraction.

skeletal muscle fiber type: Not all fibers within Skeletal muscles are the same. Different fiber types contract at different speeds, are suited to different types of activity and vary in color depending on their Myoglobin (an oxygen carrying protein) content [1].

The sites of skeletal muscles in human body:

- Muscles of the head and neck.
- The muscles of trunk.
- The muscles of upper extremity.
- The muscles of lower extremity.

The following are some terms relating to muscle features that are used in naming muscles.

- **Size:** vast us (huge); Maximus (large); long us (long); minimums (small); braves (short).
- **Shape:** deltoid (triangular); rhomboid (like a rhombus with equal and parallel sides); latissimus (wide); terse (round); trapezius (like a trapezoid, a four-sided figure with two sides parallel).
- **Direction of fibers:** rectus (straight); transverse (across); oblique (diagonally); orbicularis (circular).
- **Location:** pectorals (chest); gluteus (buttock or rump); brachii (arm); supra- (above); infra- (below); sub- (under or beneath); lateralis (lateral).
- **Number of origins:** biceps (two heads); triceps (three heads); quadriceps (four heads).
- **Action:** abductor (to abduct a structure); adductor (to adduct a structure); flexor (to flex a structure); extensor (to extend a structure); elevator (to lift or elevate a structure); masseter (a chewer)[1].

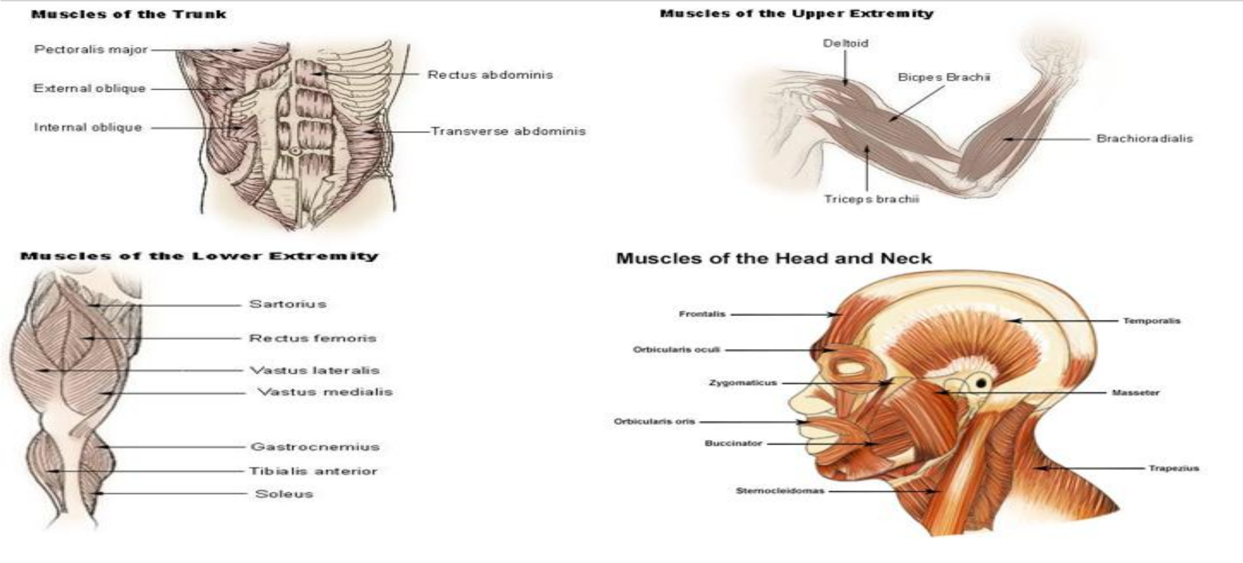

Figure 2.3 : The sites of skeletal muscles[1] .

2.3.2 Smooth Muscle

Smooth muscle is also sometimes known as involuntary muscle due to our inability to control its movements, or Unstrained as it does not have the stripy appearance of Skeletal muscle. Smooth muscle is found in the walls of hollow organs such as the Stomach, Oesophagus, Bronchi and in the walls of blood vessels. This muscle type is stimulated by involuntary neurogenic impulses and has slow, rhythmical contractions used in controlling internal organs, for example, moving food along the Esophagus or contracting blood vessels during Vasoconstriction [3].

Smooth muscle contraction**:**

1. Smooth muscles contain filaments of actions and myosin.

2. Lack transverse tubules and S.R. is not well developed.

3. Display rhythmicity (spontaneous repeated contractions) , responsible for peristalsis (alternate contraction and relaxation) .

4. Lack troponin (protein that binds to Ca^{2+}) , instead calmodulin binds to Ca^{2+} .

5. Both Acetylcholine & norepinephrine are neurotransmitters for smooth muscles.

6. Hormones and stretching affect smooth muscle contractions.

7. Can contract for a long period of time [3].

2.3.3 Cardiac Muscle (Heart Muscle)

This type of muscle is found solely in the walls of the heart. It has similarities with skeletal muscles in that it is striated and with smooth muscles in that its contractions are not under conscious control. However this type of muscle is highly specialized. It is under the control of the autonomic nervous system, however, even without a nervous impute contractions can occur due to cells called pacemaker cells. Cardiac muscle is highly resistant to fatigue due to the presence of a large number of mitochondria, myoglobin and a good blood supply allowing continuous aerobic metabolism [4].

a) unique arrangement of actins and myosin filaments produces the cross- striations (an optical illusion the microscope), and rapid contraction with powerful forces involved.

b) muscle cells are joined by intercalated disks, and allow muscle groups to form branching networks - both features are necessary for cardiac muscle to function as a unit (″ sanctum″).

c) SR and T tubules are well developed, so a large amount of calcium can be released rapidly through the T tubules.

d) contains more mitochondria in each muscle cell than skeletal and smooth muscles, providing more ATP energy for continuous contraction [4].

2.4 Muscle Aches

- Muscle spasm
- Muscular dystrophy
- Muscle strains

2.4.1 Muscle Spasm

Muscular spasm is a common problem that is common to all. It is an involuntary constriction of one or more muscles in the body. This may cause stiffness. Spasms often occur after exerting exercise without physical preparation. And adequate warm-up This cramping is known as the spasm of effort, caused by the lactic acid collected in the muscle and these convulsions continue from a few seconds to several minutes.

causes of muscle spasm: There are many reasons that may lead to muscle spasms, the most famous, The lack of minerals and salts in the body or depletion such as calcium and magnesium is one of the main reasons that may lead to muscle spasm ,Insufficient blood supply to the muscles, poor oxygen access due to a narrowing of the femoral arteries, and insufficient blood supply to the arteries due to sleep in the wrong way , Persistent muscle stress or pressure on a nerve may increase the risk of muscle injury, The weather plays an important role in the health of the muscles. A physical effort under hot sun rays can lead to a heavy depletion of sodium chloride through sweating, It is therefore advisable to drink plenty of water and salt food to compensate for the lost salts from the body. These convulsions from a few seconds to several minutes , Cold weather also plays a role in the process of spastic muscle contraction, and convulsions may reach the neck , There are several factors that, if combined, may cause muscle spasms, such as disorders of the thyroid glands, diabetes, neurological diseases, anemia or hypoglycemia [5].

2.4.2 Muscular Dystrophy

Muscular dystrophy is a group of disorders characterized by a progressive loss of muscle mass and consequent loss of strength.

The most common form of muscular dystrophy - Duchene muscular dystrophy - typically affects young boys, but other variations can strike in adulthood.

Currently, there is no cure for muscular dystrophy, but certain physical and medical treatments can improve symptoms and slow the disease's progression. The condition is caused by mutations that interfere with the production of muscle proteins necessary to build and maintain healthy muscles.

The disease is genetic, and consequently, a history of muscular dystrophy in the family increases the chance of an individual developing the disease [6].

2.4.3 Muscle Strains

A muscle strain, or pulled muscle, occurs when your muscle is overstretched or torn. This usually occurs as a result of fatigue, overuse, or improper use of a muscle. Strains can happen in any muscle, but they’re most common in your lower back, neck, shoulder, and hamstring, which is the muscle behind you thigh [7].

Chapter Three

Physics of ultrasound

3.1 Definition

3.2 Generation of Ultrasound

3.3 Continuous versus pulsed ultrasound

3.4 Physical Principles of Ultrasound

3.4.1 Wave Characteristics

3.4.2 Ultrasound Intensity

3.4.3 Ultrasound Velocity

3.5 Attenuation of Ultrasound

3.5.1 Reflection of US waves

3.5.2 Refraction of US waves

3.5.4 Absorption of US waves

3.5.5 Scattering of US waves

3.5.6 Transmission of US waves

3.6 Techniques of Application

3.7 Effect of Ultrasound

3.8 Technique of Ultrasound

3.9 Methods of Sound wave Transmission

Chapter Three

Physic of Ultrasound

3.1 Definitions

Ultrasound therapy is a medical treatment device that supplies a mechanical vibration with a sequence above 20 kHz. In practice, the frequencies used for treatment range between 0.7 to 3 MHz [8].

3.2 Generation of Ultrasound

The piezoelectric effect is exhibited by certain crystals that, in response to applied pressure, develop a voltage across opposite surfaces. This effect is used to produce an electrical signal in response to incident ultrasound waves. The magnitude of the electrical signal varies directly with the wave pressure of the incident ultrasound. Similarly, application of a voltage across the crystal causes deformation of the crystal—either compression or extension depending upon the polarity of the voltage. This deforming effect, termed the converse piezoelectric effect, is used to produce an ultrasound beam from a transducer [8].

3.3 Continuous versus pulsed ultrasound

Continuous:

This setting is indicated for sub acute, chronic conditions with no active inflammation. Sound waves are emitted continuously throughout the treatment. Because of the amount of friction created in the tissue, heat is created .

Pulsed:

Pulsed ultrasound is beneficial in acute conditions, inflammatory responses, nerve entrapment and neuromas in scar tissue. Sound wave propagation is intermittent, retaining the mechanical effects of mild cavitation and micro massage without any thermal effects [9].

3.4 Physical Principles of Ultrasound

In this section we will talk about the physical properties of ultrasonic waves.

3.4.1 Wave Characteristics

The compression and rarefaction of molecules is represented graphically as a sine wave alternating between a positive and negative deflection from the baseline. A wavelength is described as the distance between one peak of the wave and the next peak. One complete path traveled by the wave is called a cycle. One cycle per second is known as 1 Hz (Hertz). The amplitude of a wave is the maximal excursion in the positive or negative direction from the baseline. The period is the time it takes for one complete cycle of the wave as shown in the figure 3.1[10].

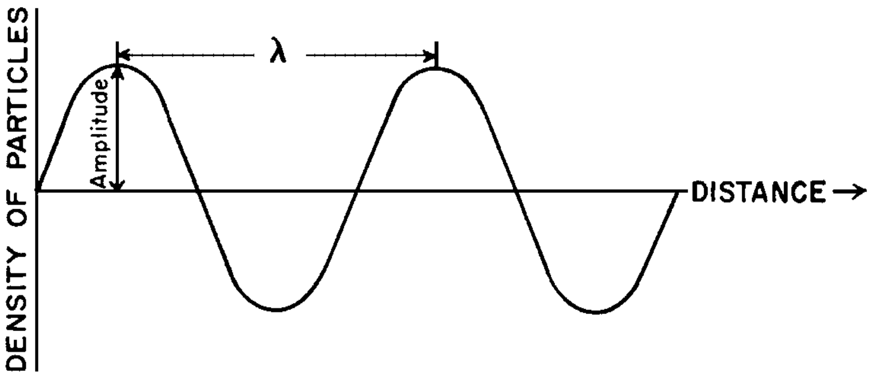

Figure 3.1: Characteristics of ultrasound[10].

3.4.2 Ultrasound Intensity

As an ultrasound wave passes through a medium, it transports energy through the medium. The rate of energy transport is known as “power.” Medical ultrasound is produced in beams that are usually focused into a small area, and the beam is described in terms of the power per unit area, defined as the beam’s “intensity.” The relationships among the quantities and units pertaining to intensity are summarized in Table 3.1 [10].

Table 3.1 : Quantities and Units Pertaining to Ultrasound Intensity [10].

Quantity	Definition	Unit
Energy(E)	Ability to do work	joule
Power(P)	Rate at which energy is transported watt	(joule/sec)
Intensity(I)	Power per unit area (a), where t = time	watt/cm2
Relationship	$\boldsymbol{I = \frac{P}{a} = \frac{E}{(a)\,(t)}}$	

Intensity is usually described relative to some reference intensity. For example, the intensity of ultrasound waves sent into the body may be compared with that of the ultrasound reflected back to the surface by structures in the body. For many clinical situations the reflected waves at the surface may be as much as a hundredth or so of the intensity of the transmitted waves. Waves reflected from structures at depths of 10 cm or more below the surface may be lowered in intensity by a much larger factor. A logarithmic scale is most appropriate for recording data over a range of many orders of magnitude. In acoustics, the decibel scale is used, with the decibel defined as [10].

$$dB = Log\ \frac{I}{I_0} \qquad (3.1)$$

Where I_0 is the reference intensity.

$$dB = 20Log\ \frac{P_m}{P_{m0}} \qquad (3.2)$$

When comparing the pressure of two waves, Eq. (3.2) may be used directly. That is, the pressure does not have to be converted to intensity to determine the decibel value.

An ultrasound transducer converts pressure amplitudes received from the patient (i.e. The reflected ultrasound wave) into voltages. The amplitude of voltages recorded for ultrasound waves is directly proportional to the variations in pressure in the reflected wave[10].

3.4.3 Ultrasound Velocity

The velocity of an ultrasound wave through a medium varies with the physical properties of the medium. In low-density media such as air and other gases, molecules may move over relatively large distances before they influence neighboring molecules. In these media, the velocity of an ultrasound wave is relatively low. In solids, molecules are constrained in their motion, and the velocity of ultrasound is relatively high. Liquids exhibit ultrasound velocities intermediate between those in gases and solids. With the notable exceptions of lung and bone, biologic tissues yield velocities roughly similar to the velocity of ultrasound in liquids. In different media, changes in velocity are reflected in changes in wavelength of the ultrasound waves, with the frequency remaining relatively constant. In ultrasound imaging, variations in the velocity of ultrasound in different media introduce artifacts into the image, with the major artifacts attributable to bone, fat, and, in ophthalmologic applications, the lens of the eye[10].

3.5 Attenuation of Ultrasound

As an ultrasound beam penetrates a medium, energy is removed from the beam by absorption, scattering, and reflection. These processes are summarized in Figure 3-2.As with x rays, the term attenuation refers to any mechanism that removes energy from the ultrasound beam. Ultrasound is “absorbed” by the medium if part of the beam’s energy is converted into other forms of energy, such as an increase in the random motion of molecules. Ultrasound is “reflected” if there is an orderly deflection of all or part of the beam. If part of an ultrasound beam changes direction in a less orderly fashion, the event is usually described as scatter[10].

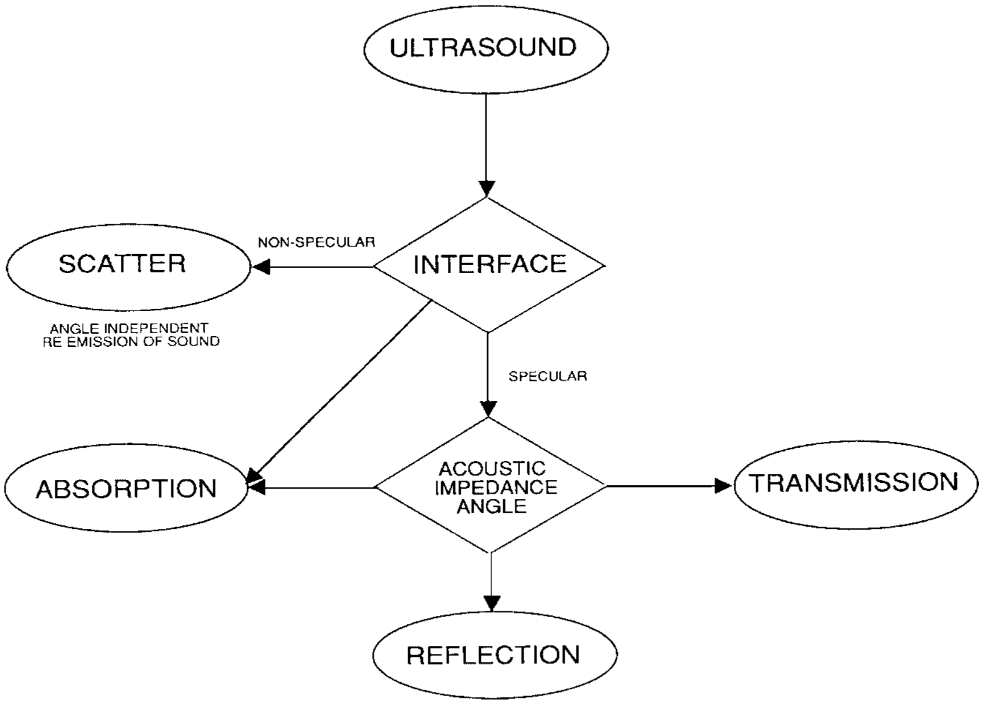

Figure 3.2 : Summary of interactions of ultrasound at boundaries of materials[10].

3.5.1 Reflection of US waves

In most diagnostic applications of ultrasound, use is made of ultrasound waves reflected from interfaces between different tissues in the patient. The fraction of the impinging energy reflected from an interface depends on the difference in acoustic impedance of the media on opposite sides of the interface as shown in the figure 3.3 [10].

The acoustic impedance Z of a medium is the product of the density ρ of the medium and the velocity of ultrasound in the medium:

$$Z = \rho c \qquad (3.3)$$

Acoustic impedances of several materials are listed in the margin. For an ultrasound wave incident perpendicularly upon an interface, the fraction α_R of the incident energy that is reflected (i.e., the reflection coefficient α_R) is [5]

$$\alpha_R = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2} \qquad (3.4)$$

where Z_1 and Z_2 are the acoustic impedances of the two media. The fraction of the incident energy that is transmitted across an interface is described by the transmission coefficient α_T , where

$$\alpha_T = \frac{4 Z_1 Z_2}{(Z_2 + Z_1)^2} \qquad (3.5)$$

Obviously $\alpha_T + \alpha_R = 1$. (3.6)

With a large impedance mismatch at an interface, much of the energy of an ultrasound wave is reflected, and only a small amount is transmitted across the interface. For example, ultrasound beams are reflected strongly at air–tissue and air–water interfaces because the impedance of air is much less than that of tissue or water.

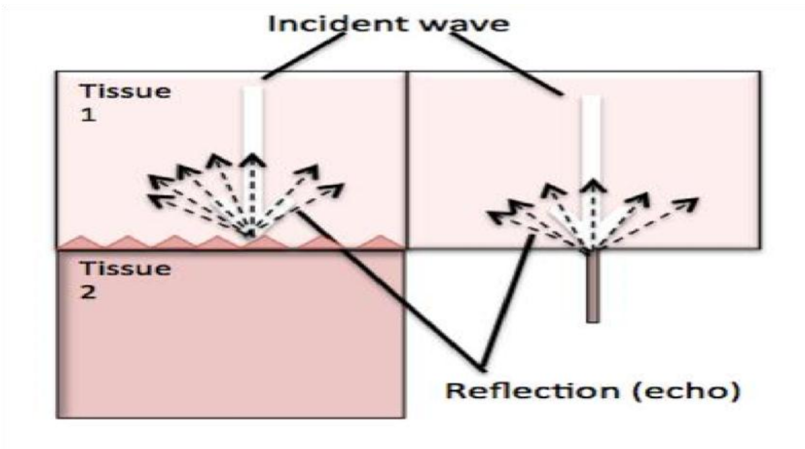

Figure 3.3 : reflection from smooth tissue[10] .

3.5.2 Refraction of US waves

As an ultrasound beam crosses an interface obliquely between two media, its direct ion tis changed (i.e., the beam is bent). If the velocity of ultrasound is higher in the second medium, then the beam enters this medium at a more oblique (less steep) angle. This behavior of ultrasound transmitted obliquely across an interface is termed refraction as show in figure 3.4 . The relationship between incident and refraction angles is described by Snell's law [10].

$$\frac{Sin \text{ of incidence angle}}{Sin\ of \text{ refractive angle}} = \frac{\text{Velocity in } incidence\ mediume}{Velocity\ in\ refractive\ mediume} \tag{3.7}$$

$$\frac{Sin\ \theta i}{Sin\ \theta r} = \frac{ci}{cr} \tag{3.8}$$

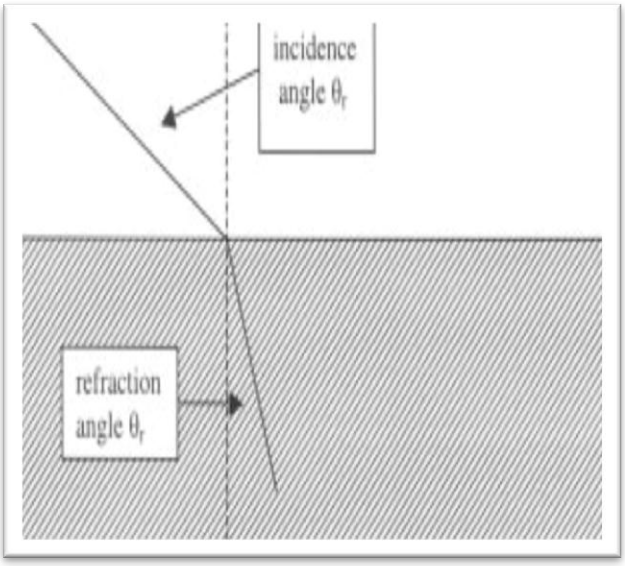

Figure 3.4: Refraction of ultrasound at an interface[10] .

3.5.4 Absorption of US waves

As the (mechanical) ultrasound energy penetrates into the body tissues, biologic effects can be expected to occur only if the energy is absorbed by the tissues. Due to the absorption the intensity of the sound waves will decrease as they penetrate further into the tissues. The absorption of ultrasound energy by biologic tissues varies. The absorption coefficient (a) is used as a measure of the absorption in various tissues. The absorption in the tissues is lower than for high frequencies. This relation ship is linear for all tissues except bone between the frequency, absorption and action at depth of ultrasound. In effect, the absorption coefficient together with reflection determines the spread of ultrasound in the body. For ultrasound, among other things, the following formula applies. This formula is true for ultrasound consisting of longitudinal waves with perpendicular incidence on homogeneous tissues [8] :

$$l(x) = lo * e^{-ax} \qquad (3.9)$$

where:

l(x) = the intensity in W/cm² at a depth x in cm

Io = the intensity in W/cm² at the surface of the body, but in the body tissue.

a = absorption coefficient (cm –1).

From this formula it emerges that the intensity of ultrasound at a certain depth depends on the absorption coefficient (a).

Table 3.2 : Absorption coefficient (a) at 1MHz and 3 MHz[8].

Medium	**Absorption coefficient (a)**	
	1MHz	**3MHz**
Tendon tissue	**1,12**	**3,36**
Muscle tissue	**0,76**	**0,28**
Fatty tissue	**0,14**	**0,42**
Skin	**0,62**	**1,86**

From the table it appears that two values are used for the absorption in muscle tissue , The marked difference is caused by the direction of the sound beam in relation to the muscle fibers. The former value applies if the sound beam is perpendicular to the muscle fibers. This is by far the most usual situation in the practical application of ultrasound. The latter value applies if the sound beam runs parallel to the muscle fibers. In the latter case the absorption is almost a factor 3 smaller. A more practical value relating to absorption is the half-value depth (D1/2). Definition: the ‘half-value depth’ in the distance in the direction of the sound beam in which the intensity in a certain medium decreases by half. The half-value depth (D1/2) as determined by the absorption coefficient can be calculated with the formula:

$$\text{Half-value depth } \left(\frac{D1}{2}\right) = \frac{0.69}{a}. \qquad (3.10)$$

Table 3.3 : Half-value depth (D1/2) of various media[8].

	1MHz	3MHz
Skin	**11,1 mm**	**4,0 mm**
Tendon tissue	**6,2 mm**	**2,0 mm**
Muscle tissue	**9,0 mm**	**3,0 mm**
Fatty tissue	**50,0 mm**	**1 16,5 mm**

Until now it has been generally assumed that the half-value depth for muscle tissue is about 3 cm. This is correct if the sound beam runs parallel to the muscle fibers, which in practice will hardly ever be the case. If the sound beam is perpendicular to the muscle fibers – as is mostly the case during treatment – the half-value depth is found to be 0.9 cm .

The consequence of the greater absorption is that the action in depth decreases. In addition it is seen that much ultrasound energy is absorbed in tendon tissue and cartilage. Possibly this is an explanation for the favorable therapeutic results of treatment of these tissues.

The greatest depth at which a therapeutic effect can still be expected is called the penetration depth *(p)*. this is the point where 10% of the applied sound intensity remains. It should be noted that this value only specifies the depth, not the local intensity of the ultrasound. The intensity of the ultrasound at the penetration depth determines whether a therapeutic effect will really no longer result at this depth. The value of p is approximated by[8] .

$$p \approx \frac{2.3}{a} \qquad (3.11).$$

Table 3.4 : Penetration depths of some media[8].

	1MHz	3MHz
Skin	**37 mm**	**12 mm**
Tendon tissue	**21 mm**	**7 mm**
Muscle tissue	**30 mm**	**10 mm**
Fatty tissue	**165 mm**	**55 mm**

3.5.5 Scattering of US waves

The ultrasound waves will scatter in all direction when the particles is very small. In case change blood density, blood pressure, irregular plasma the scattering will increase. Show in Figure 3.5 [10].

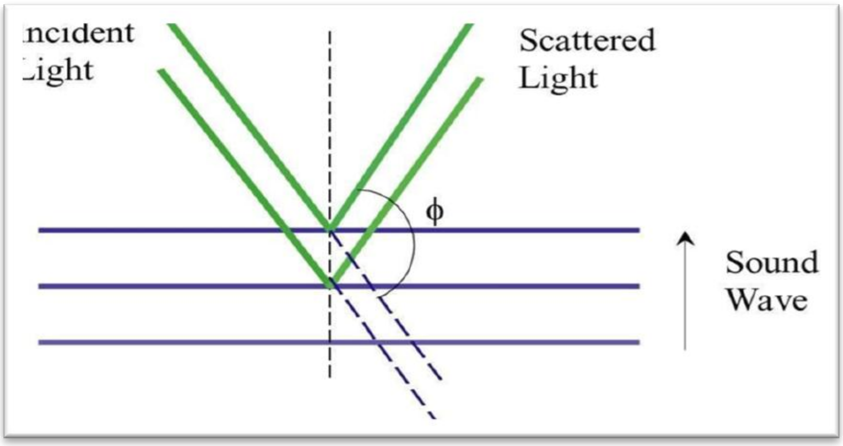

Figure 3.5 : scattering of Ultrasound waves[10].

3.5.6 Transmission of US waves

Not all of the sound-wave is reflected, therefore some of the wave continues deeper into the body, the segments will absorbed some of waves that will convert into heat and other waves will reflect from deeper tissue structures. Show in figure 3.6 [10]
.

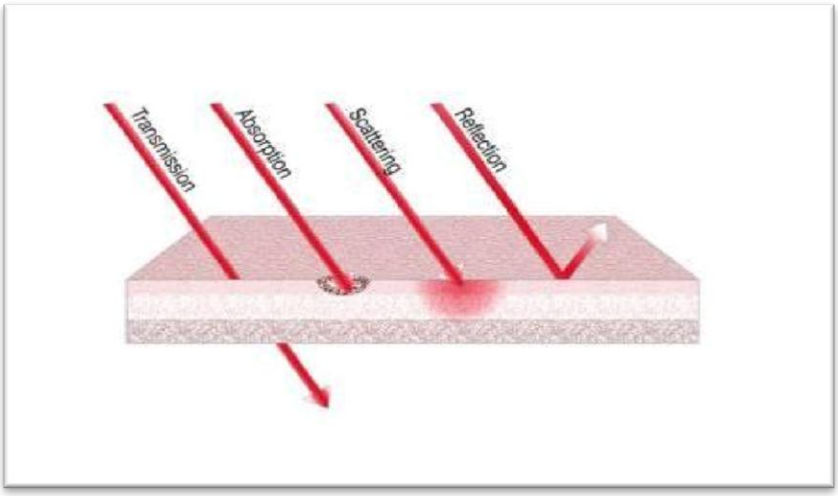

Figure 3.6 Transmission of waves[10].

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3.6 Techniques of Application

Treatment area **:** the skin should be clean and dry before applying the coupling gel. The treatment area should be no more than twice the size of sound head.

Transmission media : The higher the water conductive medium, the less the ultrasound energy is absorbed by the medium and the more energy is available to produce thermal effect. Less efficient mediums heat up, resulting in surface warmth to patient. In order of efficiency:

- Water.
- Aqueous gel (conducts 96% of sound).
- “Hydro” gel, (brand x), 68% of sound conducted.
- Mineral oil.
- Coupling lotion.

Treatment time: Treatment time is generally between 5 and 10 minutes. Never treat over 15 minutes regardless of treatment area.

Frequency of treatment : Acute conditions may be treated using low intensity or pulsed ultrasound once or even twice daily for 6 to 8 days until acute symptoms such as pain and swelling subside. In chronic conditions, treatment may be done on alternating days. Ultrasound treatment should continue as long as there is improvement. If no improvement is noted following three or four treatments, ultrasound should be discontinued, or different parameters (i.e., duty cycle, frequency) employed. Typically recommended treatment times have ranged between 5 and 10 minutes in length. The energy produced with 3 MHz ultrasound is absorbed three times faster than that produced from 1 MHz ultrasound. Ultrasound treatments are similar to exercise session in that each session builds on the previous one. For most conditions and whenever possible, daily ultrasound treatments will provide the most benefits to the patient.

Penetration of ultrasound: Depth of penetration is dependent on the frequency of the machine[9].

3.7 Effect of ultrasound

Mechanical effect:

- Changes in volume of the body cells of the order of 0.02%.
- Changes in permeability of the cell and tissue membranes.
- An improved exchange of metabolic products.

Thermal effect : Micro massage of the tissue leads to generation of frictional heat ,the amount of heat depends on a number of factors, form of US continuous or pulsed ,the intensity and the duration of treatment .In addition the absorption coefficient plays an important part ,the temperature in muscle tissue increases by 0.07c per second for continuous US of 1w/cm2 .Heat is especially generated at sites of reflection of US This reflection occurs particularly at boundaries between tissue with different specific a caustic impedance. Because of reflection. Interference phenomena may result that lead to an increase in intensity. Reflection takes place mainly at bony tissue (55%). The generation of heat as result of this increase in intensity is marked in the periosteum and may lead to periosteal pain. This problem is much less marked when pulsed US energy is used because the generated heat is wholly or partly dissipated between the pulses. Thus the thermal effect is low .

Biologic effects:

- Promotion of blood circulation. - muscle relaxation.

- Increased membrane permeability.
- Effect on peripheral.
- Reduction of pain .

Side effects:

- Tissue damage –high intensity causes a marked mechanical peak loading of the tissue, the extreme pressure differences developing because of exposure to US may cause cavitation in the tissue as the collapse of the bubbles causes a great local rise in temperature .
- Reduction of the blood-sugar level.
- Fatigue.
- Nervousness.
- Irritation.
- Anorexia.
- Constipation.
- Tendency to the cold.

These side effects are all thought to result from over dosage[9].

3.8 Technique of Ultrasound

- Direct contact between treatment head and body .
- treatment under water.
- Combination US with low-frequency.
- Combination US with medium frequency as interferential.
- Sonophoresis.

3.9 Methods of Sound wave Transmission

- Direct Contact- When using the direct technique, the ultrasound head is put against the skin with only a thin layer of couplet (gel or lotion) in between. Considerations when using this technique are the amount of soft tissue over the bone in that area ("bony" areas may be better suited to indirect treatment, described below) and the size of the sound head (large sound heads may require the indirect technique when treating a small area).

- Indirect - When putting the sound head against the skin is not advisable or possible; the indirect technique may be used. The sound head is held approximate 0.5 to 1.0 cm away from the skin, and the sound waves are dispersed into a medium for this short distance, then into the tissue. This is suggested for irregular body parts and bony prominences with little soft tissue coverage, and for treating small areas with a large sound head. There are two indirect techniques; underwater (immersion) or the balloon (bladder) technique [9].

Chapter Four

System Design

4.1 : Introduction

4.2 : Block Diagram

4.2.1 Oscillator

4.2.2 Common collector

4.2.3 Inverting buffer

4.2.4 Driving circuit

4.2.5 Step-up transformer

4.2.6 Transducer

4.2.7 Power supply

Chapter Four

Project Design

4.1 Introduction

A medical device that can treat the pain of muscles using Ultrasonic Waves, will be designed an ultrasonic Transmitter will be used to produce waves that can penetration the body and reach to muscles transmitter need a AC source, to generate a sin wave oscillator is needed , and then the signal goes through a several stages , to turn on the probe through vibrations of piezoelectric crystal , to improve the contact of probe with the skin a gel is needed.

4.2 Block Diagram

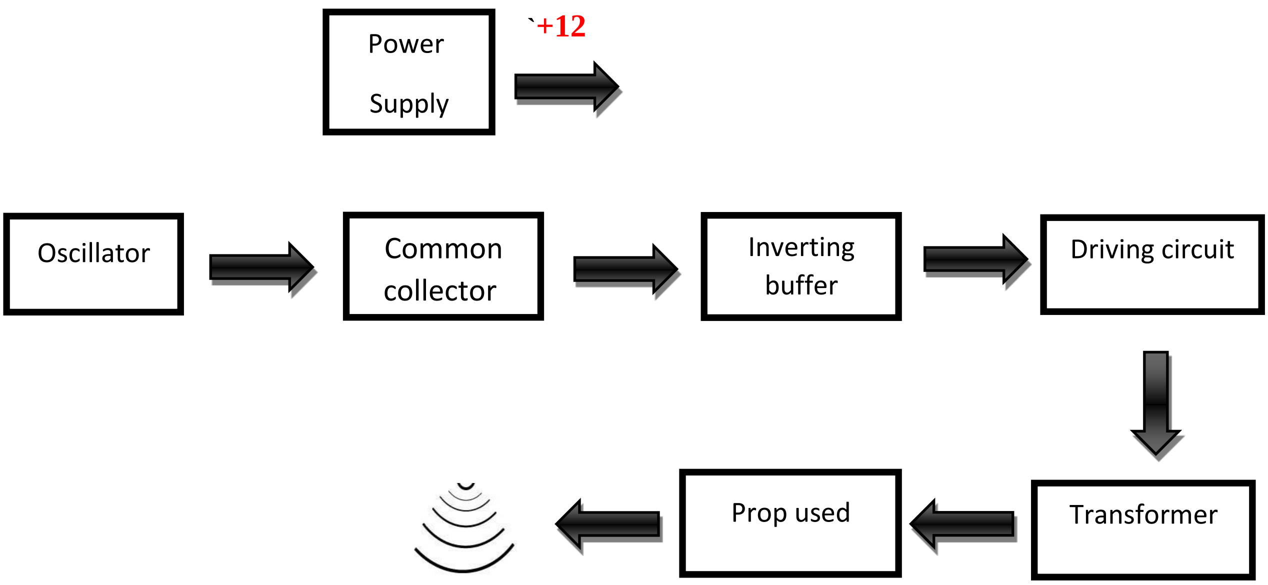

Figure 4.1 : Block diagram of the ultrasound therapy.

The following sections talk about talks about the main components.

4.2.1 Oscillator

The circuit consist oscillator (type Hartley). That generated signal ,adapted with a stage consisting of a common collector circuit.

The oscillators are electronic circuits makes a respective electronic signal generally the sine wave and the square wave. It is very important in other types of the electronic equipment, the oscillator converts the direct current from the power supply to an alternating current and they are used in many of the electronic device.

There are several types oscillators Armstrong Oscillator, Crystal Oscillator, hartley oscillator, RC Phase Shift Oscillator, Colpitts Oscillators , Crystal Oscillator,Cross-Coupled Oscillator, Dynatron Oscillator , Optoelectronic Oscillator, Phase Shift Oscillator, Wine Bridge Oscillator, Robinson Oscillator and Tri-Tet Oscillator.

The frequency of oscillation is strictly maintained at 1MHz and, on the emitter of transistor Q_4, the signal ,with an amplitude of up to 11 volt, is usually to such level for a duration of 600µs while it drops to 2 volt for a duration of 300µs.

Hartley oscillator shown in figure 4.2 is used in this project ,because it is one of the classical LC feedback circuits , used to generate high frequency waveforms or signals , it is a particularly useful circuit for producing good quality sine wave signals in the RF rang, (30kHz to 30MHz) , and can be implemented by using different circuit configurations by using a bipolar junction transistor (BJT) as the amplifiers active stage of the Hartley oscillator, we can also use either a field effect transistor, (FET) or an operational amplifier, (op-amp), in the oscillator circuit that uses a capacitor and two inductors in order to create a resonant frequency ,and the major parts of the Hartley oscillators are the amplifier section and the tank section. The tank section consists of inductors and capacitors, each section produces a sine wave voltage , When the DC supply (Vcc) is given to the circuit, the current starts raising and begins the charging of the capacitor C. Once C is fully charged, it starts discharging through L1 and L2 and again starts charging, The frequency or the amount of feedback(the feedback taken from the tap point of inductor) depends on the position of the "tapping point" of the inductor,and the Mutual inductance is an additional effective amount of inductance caused by the magnetic field created around one inductor (or one part of a tapped inductor) inducing a current into the other inductor. the equivalent inductance is calculated by the formula:

$$L_{eq} = L1 + L2 \pm 2M \qquad (4.1)$$

For a practical circuit, if L1 = L2 = L and the mutual inductance is neglected then the frequency of oscillations can be simplified as The actual value of M depends on how effectively the two inductors are magnetically coupled, which among other factors depends on the spacing between the inductors, the number of turns on each inductor, the dimensions of each coil and the material of the common core. For a practical circuit, if L1 = L2 = L and the mutual inductance is neglected then can simplified the formula like this

$$Leq = L1 + L2 \qquad (4.2)$$

The advantages for used the Hartley oscillator :

• Instead of two separate coils as L1 and L2, a single coil of bare wire can be used and the coil grounded at any desired point along it.

• By using variable capacitor or by making core movable (varying the inductance), frequency of oscillations can be varied.

• The amplitude of the output remains constant over the working frequency range.

• Very few components are needed including either two fixed inductors or a tapped coil.

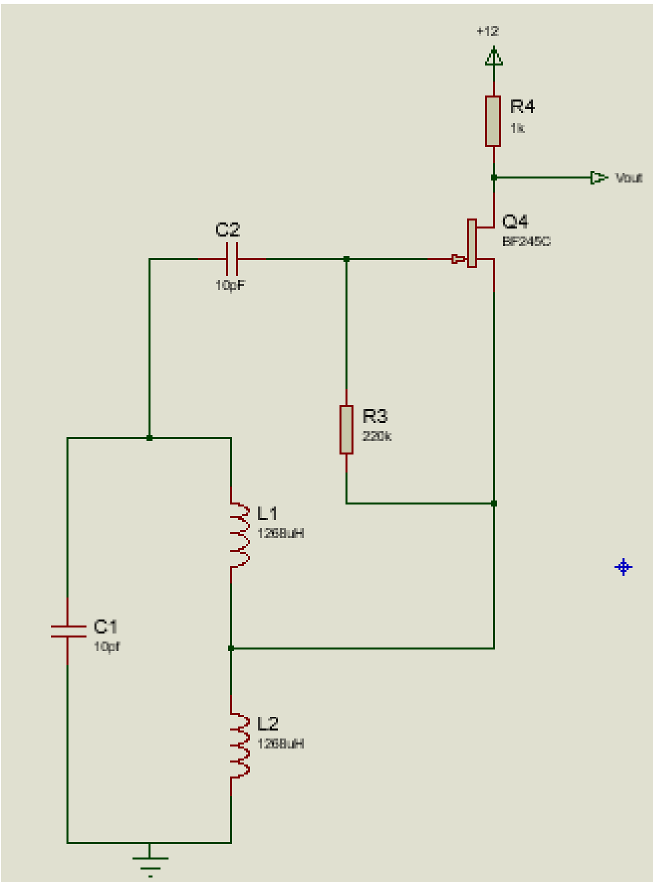

Figure 4.2: Hartley oscillator.

In this circuit, Hartley oscillator frequency is calculated based on the formula frequency.

$$f = \frac{1}{2\pi\sqrt{LeqC}} \qquad (4.3)$$

where :

C : is the value of the capacitor

Leq: is the equivalent inductance of the inductance of the inductors in series.

The calculation uses a variety of inductor and capacitor values, tries to take into account that for bread boarding purposes, large capacitor values are usually very hard to find. Components easily obtained for capacitors are values from 1pF to 4700µF,and the Inductor values are most commonly used in the nanohenries to microhenries range. Just like with capacitors, large values for inductors such as in the mill henry range are generally avoided due to the fact that capacitors in the mill farads range are hard to obtain and not easily accessible. The desired frequency is 1MHz, let Leq= 1268 µH, result in C= 10Pf.

In the project designed the Hartley oscillator with JFET, because the output from the JFET's source has the same phase as the signal at its gate (or base) and roughly the same voltage as its input (which is the voltage across the entire tank circuit), but the current is amplified, it is acting as a current buffer.

4.2.2 Common Collector

In electronics, a common collector amplifier is one of three basic single-stage bipolar junction transistor (BJT) amplifier topologies, typically used as a voltage buffer. In this circuit the base terminal of the transistor serves as the input, the emitter is the output, and the collector is common to both as shown in figure 4.3.

The common collector circuit can be shown mathematically to have a voltage gain of almost unity:

$$A_{v}= \frac{V_{out}}{V_{in}} \approx 1 \qquad (4.4)$$

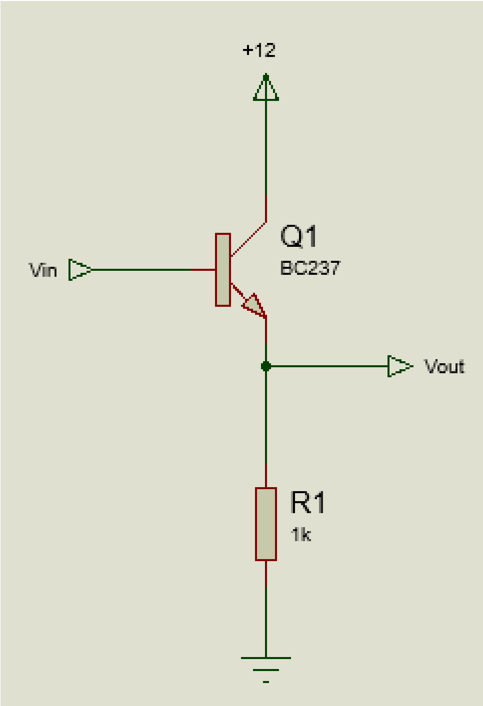

Figure 4.3:Common collector.

4.2.3 Inverting Buffer

In this project used 4049 to invert the signal to be suitableness, and good to use because it need only one single supply, which is consist six not gate , but need to use a one gate and it having a high input supply voltage with a maximum current rating of 1mA at 18v,the main use of this IC is to create a voltage multiplier circuit by simply adding resistor, capacitor, and diode with it.

4.2.4 Driving circuit

A driving circuit is designed in the project in order to increase the o/p power of the sinusoidal signal .It consists of two main parts push-pull, and mos-fet transistor circuit.

- Push- Pull:

It is used to drive the current in either direction through the load. The output of a typical push pull amplifier consists of two transistor, one sourcing current through the load while the other one sinking the current through the load, Push pull amplifiers are superior as compared to single ended amplifiers (using a single transistor at the output for driving the load) in terms of performance and distortion .

- MOS-FET

Transistor**:** n-channel, enhancement mode, logic level, field-effect power transistor. This device has very low threshold voltage and extremely fast switching making it ideal for battery powered applications and high speed digital interfacing ,and the drain of it with free Wheeling diode (Protection circuit) , It is used to protect the MOS-FET from the return current. The couple of transistor Q_1 And Q_2 which drive the power MOS-FET type "n" T directly, and the zener diode Z_1fixes the max , voltage level which can reach the MOS-FET gate as shows in figure 4.4 .

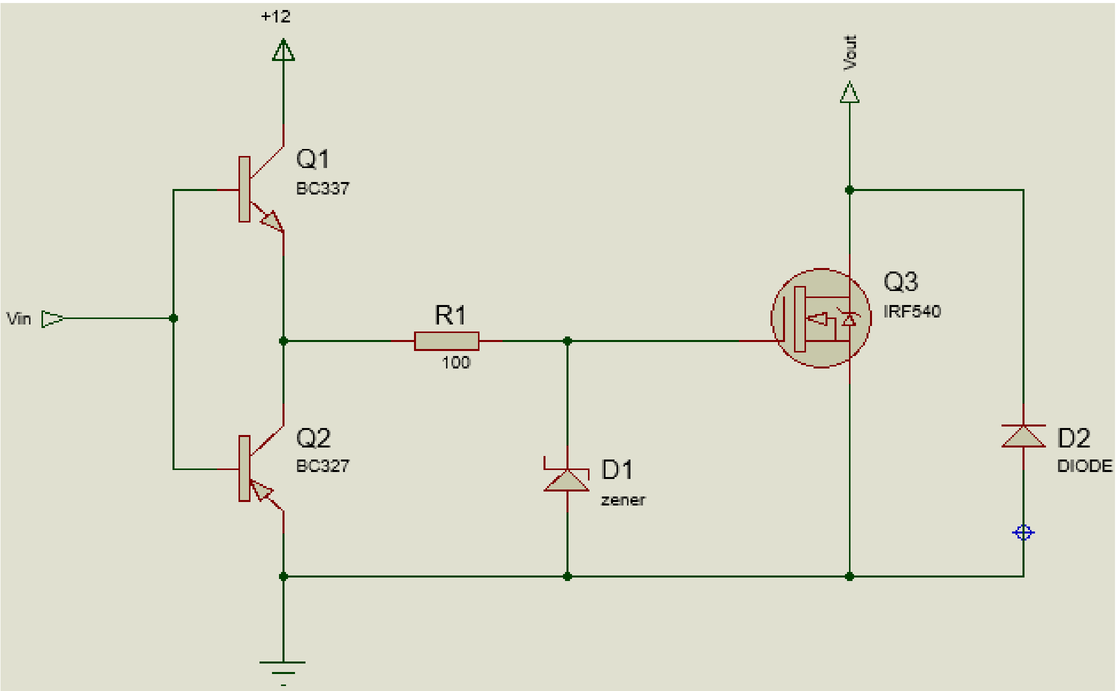

Figure 4.4 : the simulation of driving circuit .

4.2.5 Step -up Transformer

In order to increase the amplitude of the driving circuit, a step-up transformer is used. The chosen transformer has the ability to work with 1MHz voltage and has the ability to increase the output voltage depending on the following equation.

On a step-up transformer there are more turns on the secondary coil than the primary coil .The induced voltage across the secondary coil is greater than the applied voltage across the primary coil or in other words the voltage has been "stepped-up" as shows in figure 4.5 .

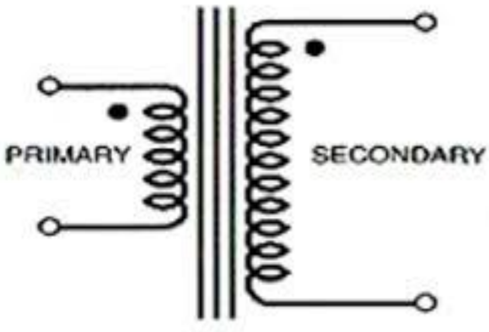

Figure 4.5: step up transformer.

The ratio of the step-up transformer is 1:2.

The relationship between the voltage and the number of turns in each coil is given by :

$$\frac{voltage\ in\ secondary\ coil}{voltage\ in\ primary\ coil} = \frac{Turns\ on\ secondary\ coil}{Turns\ on\ primary\ coil} \tag{4.5}$$

OR

$$\frac{V_S}{V_p} = \frac{N_S}{N_p} \tag{4.6}$$

- The calculation of the number of primary turns :

V_p (voltage of primary) =37.6 .

I (current0 =.5A.

Current density (S)= 3.

Power = current * voltage (4.7)

$$I_P = \frac{power}{v} = 1.14A \tag{4.8}$$

The number of primary turns = $V_p * 5.135 = 194$

The cross sectional area of the wire = $\frac{I}{S}$ =0.38mm^2 .

The diameter of primary wire = $\sqrt{\frac{0.38}{0.785}}$ =0.7mm.

- The calculation of the number of secondary turns :

V_p (voltage of secondary) =86 .

I (current) =0.5A.

Current density (S)= 3.

Power = current * voltage (4.9)

The number of secondary turns = $V_p * 5.676 = 489$.

The cross sectional area of the wire = $\frac{I}{S}$ =0 .16mm^2

The diameter of secondary wire = $\sqrt{\frac{0.16}{0.785}}$ =0.461 = 0.45mm.

4.2.6 Transducer of ultrasound

The circuit to study the ultrasound therapy is based on a ultrasound diffuser consisting of piezoelectric ceramic having the property to mechanically vibrate to a determinate frequency if crossed by a variable voltage at a proper frequency as shown in figure 4.6.

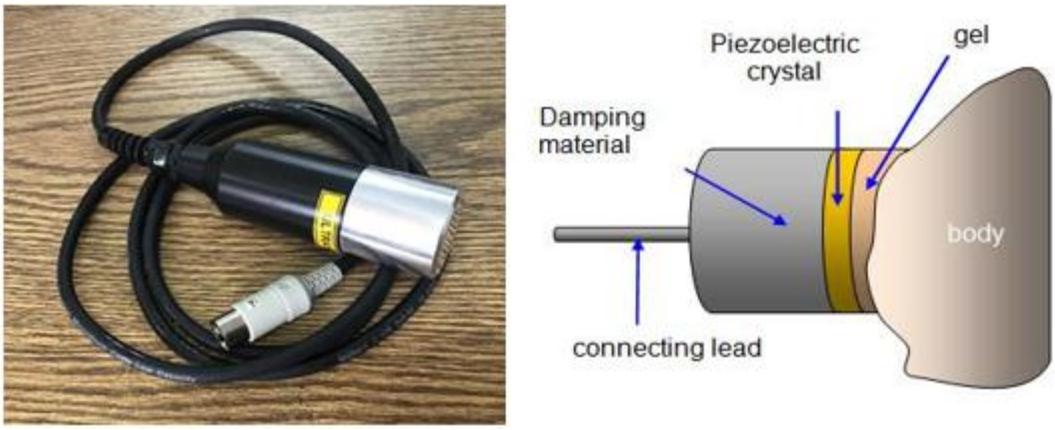

Figure 4.6 : Piezoelectric transducer of ultrasound.

These kind of the ceramic transducers operates on a very narrow band and their characteristic power and resonance frequency is function of the kind of operation, the dimensions and the shape .

An energy is produced appearing as oscillation of particles of the tissues in which they propagate at a frequency above the max. audible sounds.

According to the application points of the stress variable electrical field, this kind of ceramic material mechanically vibrates with different characteristics. The excitation voltage can be applied so to generate mechanical vibration in the thickness, the width or radially if the ceramic material is cylindrical.

The main component of this ceramic is the titanium-zirconate, which enables a good operation at high temperatures and a high electromechanical coupling enabling the use with equipment having air diffusors or mechanically charged.

The resonant frequency of the crystal is partly determined by the thickness of the piezo-electric material (PZT) and consequently the frequency of the ultrasound is so determined as well. Moreover, this implies that the sound head and the equipment must be mutually adjusted, so that the treatment head cannot be used with another piece of ultrasound equipment unless calibration is performed. Technical innovation has solved this problem in the Sonopuls apparatus, where the treatment heads are fully interchangeable between different instruments of the same type and proper adjustment is automatically performed.

As a result of the alternating current applied to the Piezo-electric material, this generates sound waves. These will propagate in the neighboring media .Because the Piezo-electric material generates sound waves bi-directional, ultrasound will also enter the treatment head. The transducer also vibrates laterally, consequently ultrasound energy in transferred to the sidewall of the treatment head via the transducer mounting. The chosen transducer has the ability to provide sinusoidal signal with 1MHz frequency. Which is the frequency needed to treat the muscle as mentioned in the preceding chapters

.

4.2.7 Power supply

all components in the project need a voltage source to activate it , by using a step down transformer from 220v to 12v , and then use a bridge rectifier (1B4B42) which enables it to pass both the positive and negative side of the alternating current input , and using a regulator (LM78120) to give an output 12v(Dc) as shown in figure 4.7.

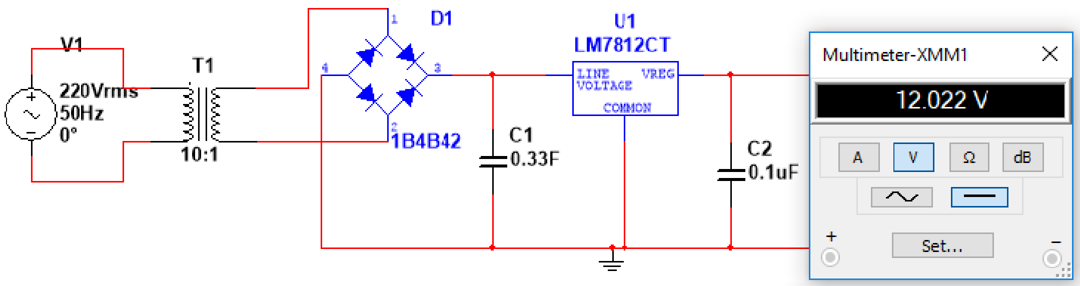

Figure 4.7 :Power supply.

Chapter Five
System Implementation and Results

5.1: System Implementation

5.1.1 Hartley Oscillator

5.1.2 Common collector

5.1.3 Inverting buffer

5.1.4 Driving circuit

5.1.5 Step -up Transformer

5.1.6 Transducer of ultrasound

5.1.7 Power supply

5.2 Challenges

5.3 Conclusions

5.1 Project Implementation

In this chapter the hardware system designed in the preceding chapter is implemented to accomplish the project as a one unit which achieves the purpose of the project. In this section, subsystems circuits will implemented before final Implementations of the system.

5.1.1 Hartley Oscillator

The wine-bridge oscillator was implemented as shown in figure 5.1.

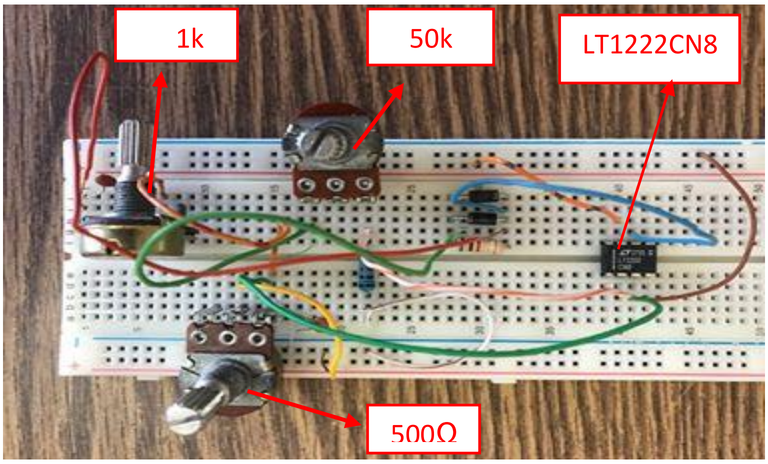

Figure 5.1 : wine-bridge oscillator..

, but the output from the Wien-bridge oscillator , as shown in figure 5.2.

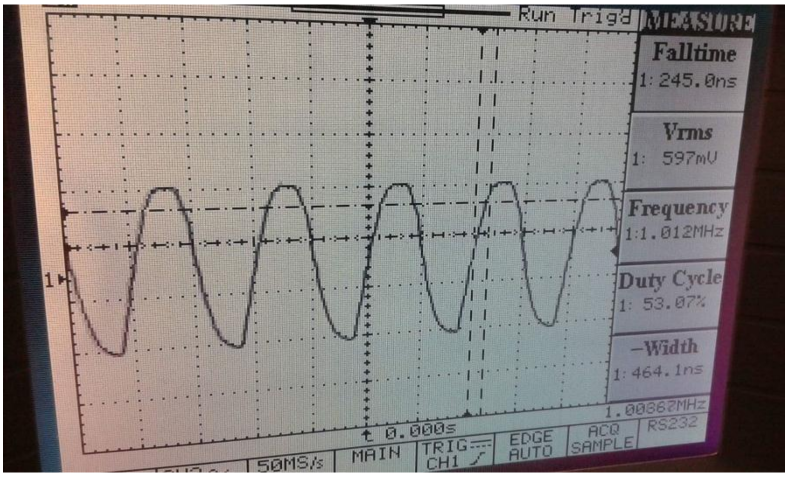

Figure 5.2: The output of wine-bridge oscillator.

,as shown in the picture a main problem for using a wine-bridge is the output voltage is not enough

After that , a Hartley oscillator was implemented on the copper plate , as shown in figure 5.3.

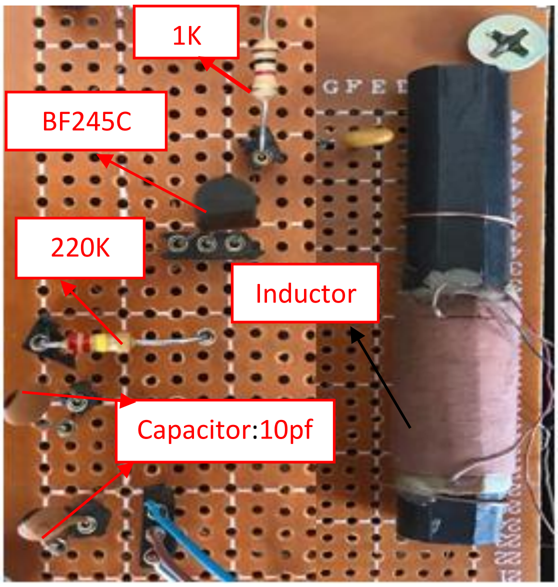

Figure 5.3: Hartley oscillator.

The measured output voltage of the circuit , which shown in figure 5.4 is pure a sinusoidal signal with a relatively high output voltage (about 10 volt) and with a specific frequency 1MHz .

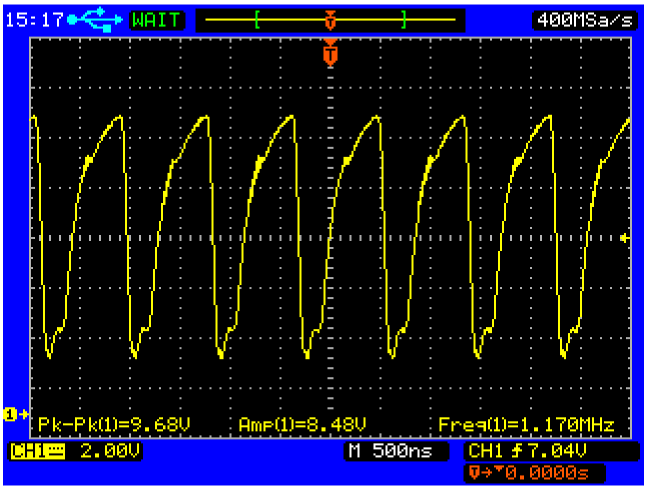

Figure 5.4 : The output of hartley oscillator.

5.1.2 Common Collector

The common collector was implemented on the copper plate, as shown in figure 5.5.

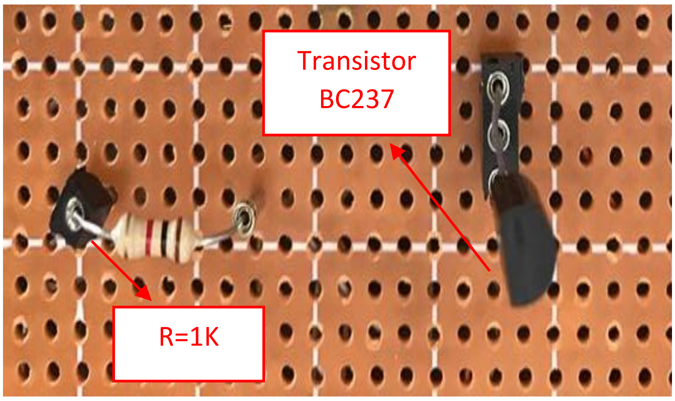

Figure 5.5: The common collector.

It has a large input impedance, so it will not load down the oscillator. The output voltage of the circuit as shown in figure 5.6.

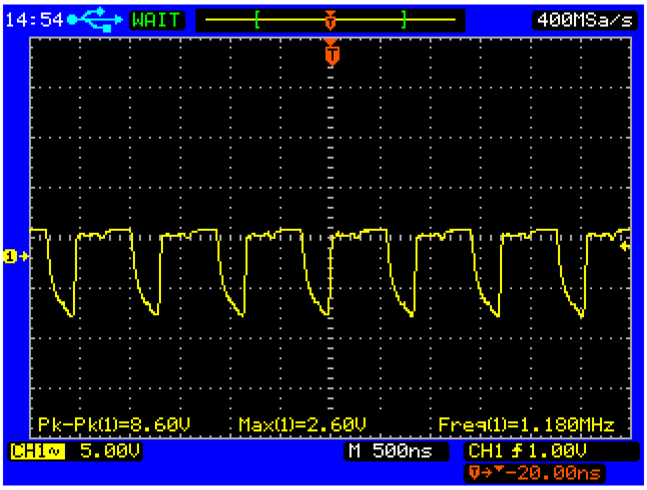

Figure 5.6 : The output of common collector.

5.1.3 Inverting Buffer

The output from common collector is connected to the input of the inverting buffer , as shown in figure 5.7.

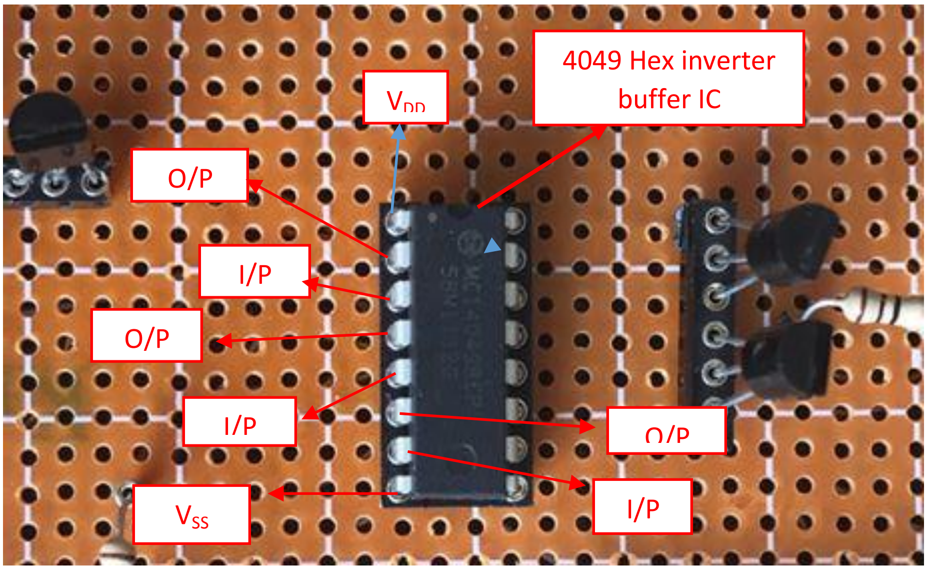

Figure 5.7 : Inverting Buffer.

this circuit is used to amplify and invert the input signal as shown in the figure 5.8.

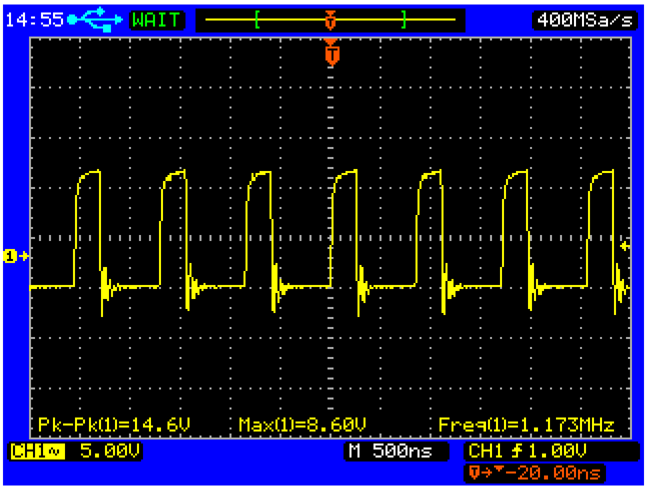

Figure 5.8: The output of inverting buffer.

5.1.4 Driving circuit

Built the driving circuit with a specific component to give a suitable output can be input to the transformer as shown figure 5.9.

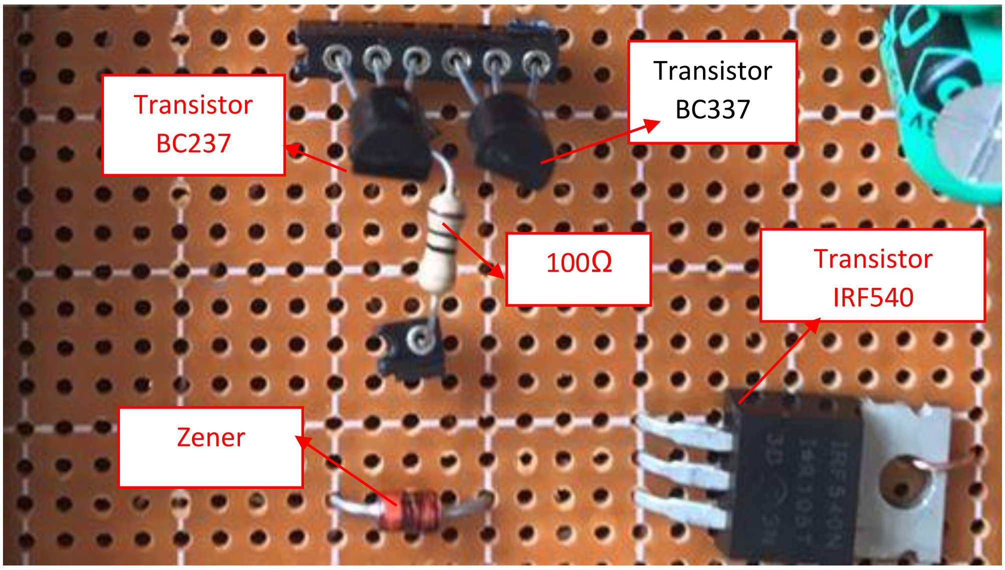

Figure 5.9: The driving circuit.

The output from the driving circuit after built on the copper plate, as shown in the figure 5.10.

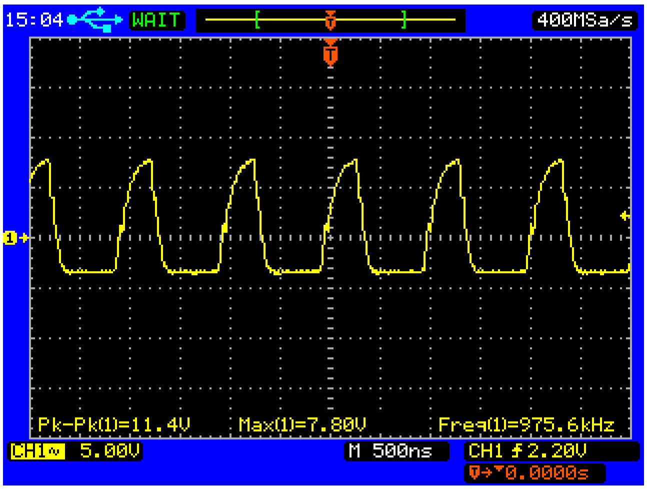

Figure 5.10:The output of driving circuit.

5.1.5 Step -up Transformer

Built the step-up transformer with the specific turns , as shown in figure5.11.

Figure5.11 : step-up transformer.

5.1.6 Transducer of ultrasound

All component and circuits implemented as a previous chapter to activate the ultrasound transducer (probe) , which is a device that produces sound waves that bounce on the body tissues, and it is a very important part of the ultrasound machine , The essential element of each ultrasound transducer is a piezoelectric crystal. It serves to generate ultrasound waves. and connected the transducer with the breadboard by a (adaptor) , which is has a six connect points , but need just a two connect points number two and four and it is just turn on with the 1MHz and after connected with the breadboard the probe became warm as show in figure 5.12.

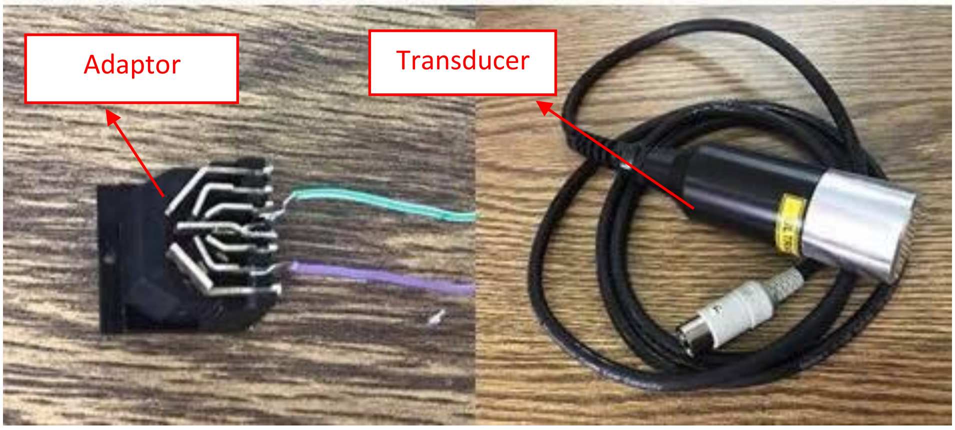

Figure 5.12: The transducer of ultrasound & the adapter.

5.1.7 Power Supply

Built the power supply with a specific component to give a suitable output ~= +12v as shown in figure 5.13.

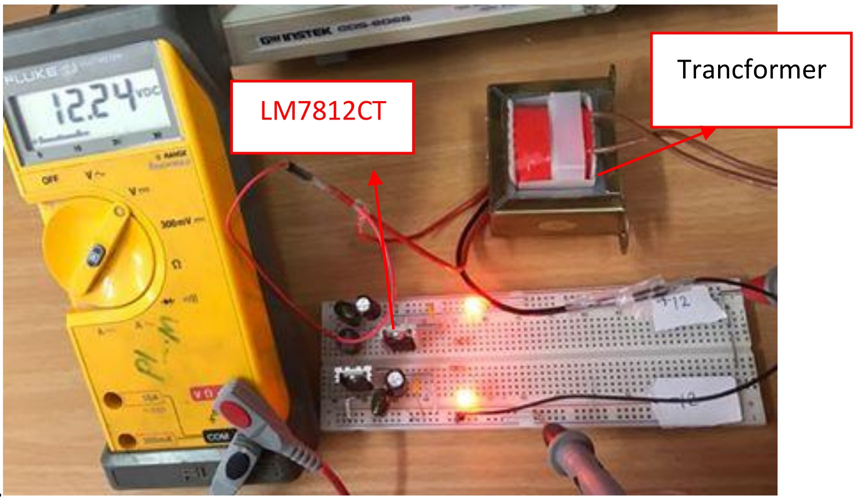

Figure 5.13: The output of power supply.

5.1.8 Overall project circuit

The overall circuit of the project is shown in the following figure 5.14.

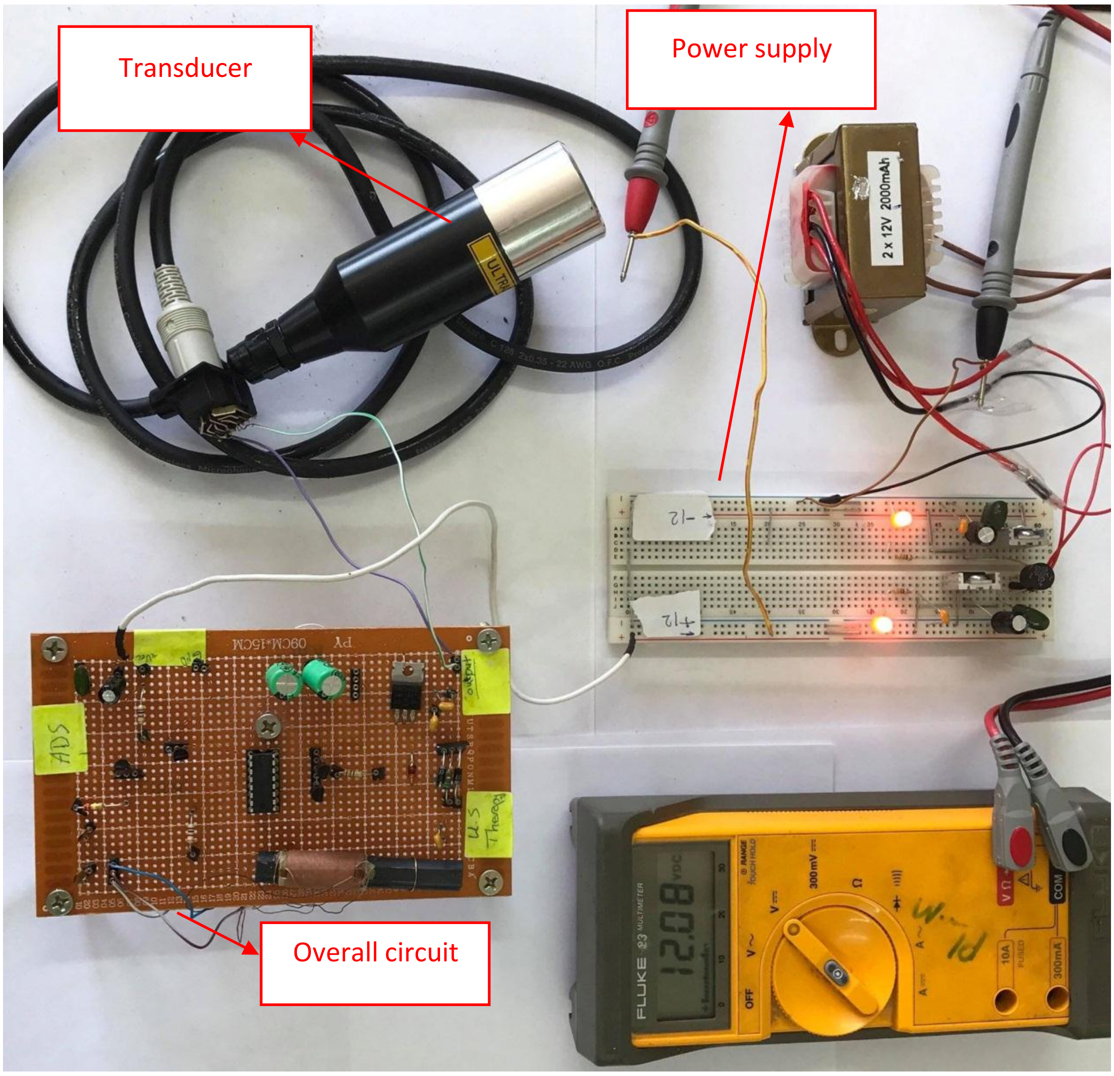

Figure 5.14: The overall project circuit.

5.2 Challenges

While designing the system , there are many challenges have been faced , such as :

- ❖ Transformer is only available for a factory in Italy , so it was done manually, but it has a huge size to use in medical device.
- ❖ Not all required components for this project are available in the Palestinian market.
- ❖ Some of the project component are so expensive.

- The high frequency and high voltage needed , made a difficulty of dealing with them and it made a noise in a signal 5. it is not easy to find a components that is use in a high frequency domain.

5.3 Conclusions

- In this project a therapy system has been implementation to activate a probe
- Therapy ultrasonic device use for muscles treatment.
- The high frequency and high voltage are oscillated the crystals in the probe and then warmed a probe.
- The box design has a small size , so can be moved from one place to another easily.

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