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Date	: 11 May 2009

TEMPERATURE MONITORING SYSTEM FOR ULTRASOUND THERAPY MACHINE

MANI A/P CHOW

Submitted to the Faculty of Electrical Engineering
in partial fulfillment of the requirements for the award of the
Bachelor of Electrical Engineering (Medical-Electronics)

Faculty of Electrical Engineering
University of Technology Malaysia

MAY 2009

I declare that this thesis entitle *"Temperature Monitoring System for Ultrasound Therapy Machine"* is the result of my own research except as cited in the reference. This thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Dedicated, in thankful appreciation for support, encouragement and understandings to my beloved father, mother, brothers, sisters, lecturers and friends.

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ABSTRACT

The use of ultrasound in therapy is based on many effects including thermal. However, this thermal effect from ultrasound therapy machine is not monitor in most of the currently available machine. The thermal effect may raise the temperature up to several degrees Celsius. However, this temperature rise may be somehow out of the allowable range and hazardous because it is possible to cause tissue damage and skin burn. Thus, this project had been implemented in order to add the safety feature of the currently available ultrasound therapy machine in market. In brief, this project is about the development of temperature monitoring system for ultrasound therapy machine. This includes the implementation of the temperature sensor circuit, analog to digital converter and graphical user interface. The complete system integration is then test for the stability and accuracy of the measurement. The results show that the accuracy of this system is more than 95 percents. In conclusion, temperature monitoring system is essential for ultrasound therapy machine. It is possible to be attached into the casing of the ultrasound therapy transducer to monitor the effect of temperature rise. For this, miniaturization is needed.

ABSTRAK

Penggunaan ultrasonik di dalam bidang terapi adalah berdasarkan pelbagai kesan termasuk pemanasan. Walau bagaimanapun, kesan pemanasan ini tidak di awasi di dalam kebanyakan mesin terapi utrasonik yang terdapat di pasaran pada masa sekarang. Kesan pemanasan ini mungkin boleh meningkat sehingga beberapa darjah Celsius. Tetapi, peningkatan suhu ini mungkin lebih daripada julat yang dibenarkan dan membahayakan pengguna kerana boleh menyebabkan kerosakan pada tisu dan juga kulit terbakar. Oleh itu, projek ini telah dilaksanakan yang bertujuan untuk menambahkan lagi ciri-ciri keselamatan yang terdapat pada mesin terapi ultrasonik yang terdapat di pasaran pada masa sekarang. Secara ringkas, projek ini ialah tentang pembinaan sistem pengawasan suhu bagi mesin terapi ultrasonik. Projek ini termasuk pembinaan litar pengesan suhu, litar penukar analog ke digit dan grafik antaramuka pengguna. Sistem yang telah lengkap dibina ini kemudian diuji kestabilan dan ketepatannya di dalam pengukuran. Keputusan menunjukkan bahawa ketepatan sistem ini adalah melebihi 95 peratus. Kesimpulannya, pengawasan suhu adalah penting bagi mesin terapi ultrasonik. Sistem ini boleh disertakan sekali di dalam tranduser terapi ultrasonik untuk mengawasi suhu. Untuk tujuan ini, pengecilan skala diperlukan.

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LIST OF SYMBOLS

$°C$	-	Degree Celsius
$°F$	-	Degree Fahrenheit
$°K$	-	Kelvin
α	-	Absorption coefficient cm^{-2}
ADC	-	Analog to Digital Converter
BNR	-	Beam Non-Uniformity Ratio
CPU	-	Central Processing Unit
GUI	-	Graphical User Interface
I	-	beam intensity in W/cm^2
I.C	-	Integrated Circuit
I/O	-	Input/Output
PC	-	Personal Computer
RAM	-	Random Access Memory
ROM	-	Read Only Memory
RTD	-	Resistance Thermo Detector
U_h	-	heat energy in watts
US	-	Ultrasound
VB	-	Visual basic

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Ultrasound is defined as sound wave having a frequency greater than the upper limit of human hearing. Although this limit varies from person to person, it is approximately 20 kilohertz (20,000 hertz) in healthy, young adults and thus, 20 kHz serves as a useful lower limit in describing ultrasound. There are two primary form of ultrasound, diagnostic and therapeutic. Diagnostic ultrasound is used for medical imaging while the therapeutic counterpart is used in the treatment of various physical ailments and fitness machines.

In fact, ultrasound has been used in therapeutic for over 60 years. This include in the management of pain, musculoskeletal injuries, inflamed tendons, soft tissue damage, strained and torn muscle, scar tissue sensitivity and tension, sprained ligaments and also in cosmetic. At the moment, recent uses of ultrasound therapy include the accelerated healing of fractures, muscle injury and thrombolysis.

Ultrasound may induce thermal and non-thermal physiological effects in tissue. Thermal effects of ultrasound upon tissue may include increased blood flow, reduction in muscle spasm, increased extensibility of collagen fibres and a pro-inflammatory response. It is estimated that thermal effects occur with the elevation of tissue temperature to about 40°C to 45°C for at least 5 minutes. However, the excessive thermal effects, seen in particular with higher ultrasound intensities and the possible failure of the machine may damage the tissue and causing burning to the skin surface.

1.2 Problem Statement

Although there are a wide variety of ultrasound therapy product, but none of them is equipped with the temperature monitoring system. However, it is important to monitor the heat produce by the product because the excessive heat that is possible cause by the failure of the machine, high intensity for long duration application could cause damage to the tissue and burn the skin surface. Thus, temperature monitoring is actually an important safety feature that must be included in an ultrasound therapy machine.

1.3 Objectives of Project

There are two objectives to achieve in this project. The first objective is to obtain the characteristics of heat increasing because of ultrasound power. Other than that, the second objective of this project is to develop hardware and software to monitor the temperature generates by the ultrasound therapy machine.

1.4 Scope of Project

There are several scope had been outlined for this projects. The scope of this project includes using semiconductor temperature sensor (LM 35), build hardware for the system and interface the hardware to computer using RS232 serial port communication, display the temperature on personal computer. The temperature sensor is required to cover the temperature from 35°C to 55°C with a resolution of 1°C.

1.5 Work Breakdown

In order to achieve the objective of this project, there are several tasks that need to be done as shown in Figure 1.1 below. These tasks are divided into three main categories that are study, design and implementation.

The related items that need to study in detail are the principles of ultrasound therapy, thermal effects from ultrasound therapy, temperature sensor, analog to digital converter, microcontroller architecture, programming for microcontroller and programming for graphical user interface.

Other than that, for this system it is needed to design the system block diagram, hardware circuit, software algorithm and software programming.

Following the design is the implementation of the hardware, software and system integration.

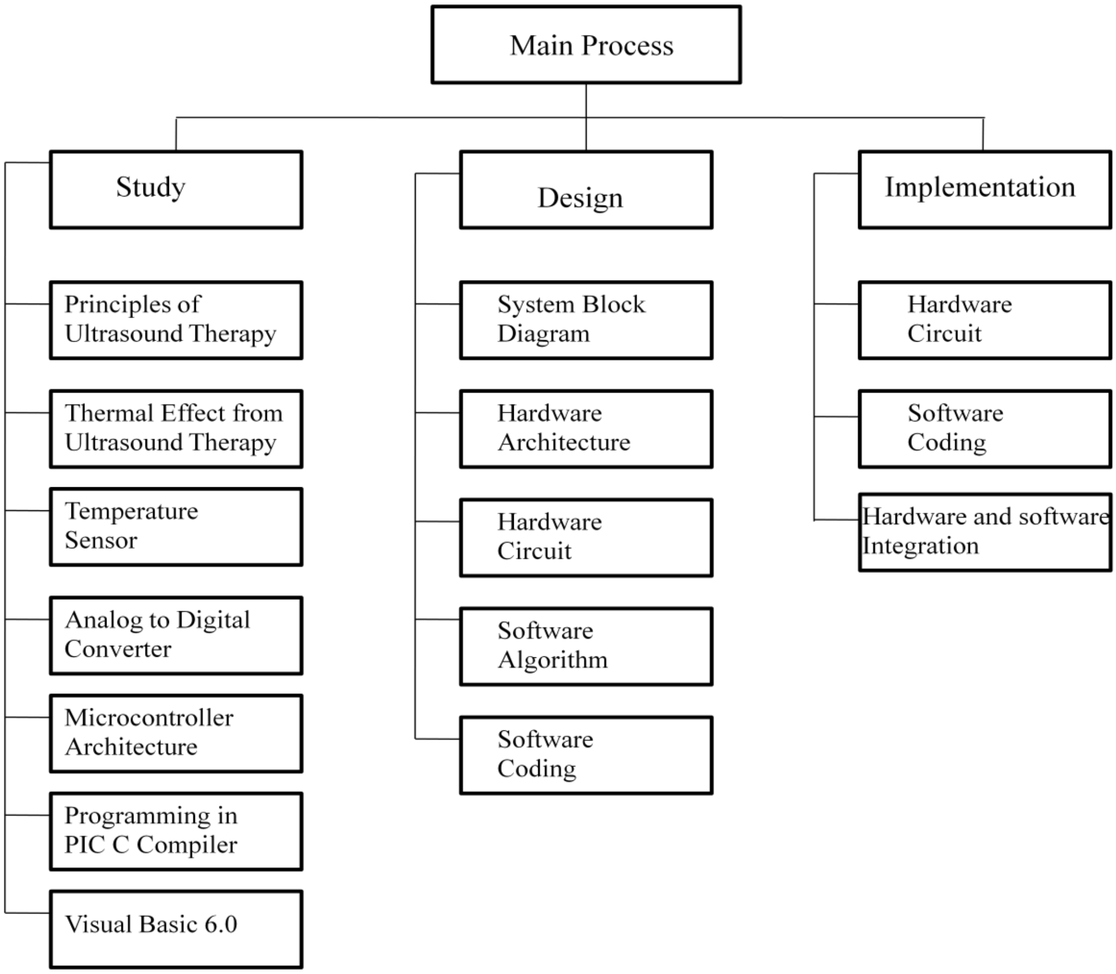


Figure 1.1 Work breakdowns for the project of temperature monitoring system for ultrasound therapy machine

1.6 Work Flow

The summary of work flow for this project is simplified into block diagram as shown in the Figure 1.2 below. The starting point of this project is the literature review and theoretical study. But, these actions are continuous as new information must be gathered from time to time in order to proceed with this project.

After having an overview of the component to include in this project, the suitable components were selected based on the scope and limitation of this project. Hardware implementations begin after the components were available. On the other hand, software implementations begin with algorithm for the analog to digital converter and continue with the graphical user interface. After that, the whole system was integrated for testing and optimization before the real demo and presentation to the panel of the final year project.

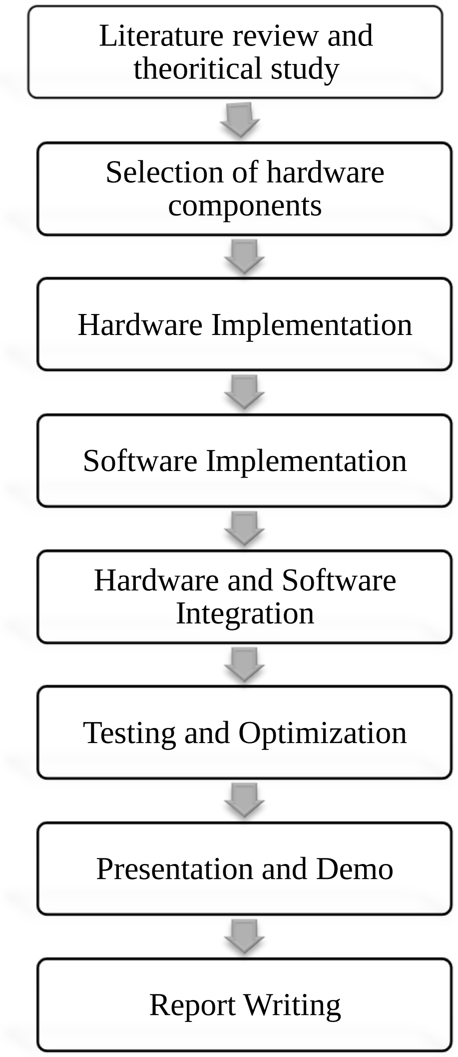


Figure 1.2 Work flow of this project

Meanwhile, the project schedule or Gantt chart of this project is included in the section 1.7. Gantt chart of Figure 1.3 and Figure 1.4 shows the detail of the works done with the time spending on it for the duration of two semesters.

1.7 Gantt Chart

Week / Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.Literature review	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Study week	Exam week
2.Study on microcontroller	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
3. Study on ultrasound therapy block diagram				■	■	■	■	■									
4.Experimental setup									■	■	■	■					
5.Data analysis												■	■				
6.Presentation														■			
7.Report writing														■	■		

Figure 1.3 Gantt Chart of the project schedule for semester 1

Week / Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Circuit implementation	■	■	■	■												Study week	Exam week
2. Software implementation					■	■	■	■									
3.Testing and optimization of system									■	■	■	■					
4.Presentation													■				
5.Demo													■				
6.Report writing														■	■		

Figure 1.4 Gantt Chart of the project schedule for semester 2

1.8 Thesis Outline

This thesis is a report of a final year project of title “Temperature Monitoring System for Ultrasound Therapy Machine”. There are five main chapters explained in detail within this thesis.

Chapter 1 explain in detail the information about the project background, problem statement, objectives, scope, work flow, Gantt chart, thesis content and work breakdown. In this chapter, the reader could find out the overview of this project and also the significant of this project.

Next in chapter 2, the related literature to this project is provided in detail. The topic explained in this chapter included medical ultrasound, therapeutic ultrasound, thermal effect of ultrasound and basic of hardware involve.

Chapter 3 is about design and implementation. In this chapter, the design and implementation step is explained in detail.

Chapter 4 contains the information about the results and discussion and the last, Chapter 5 summarize about this project

CHAPTER 2

LITERATURE REVIEW

2.1 Medical Ultrasound

Ultrasound has been employed in medicine for more than 50 years. The early application of ultrasound for medical treatment was introduced in Germany in the late 1930s and in the United States in the late 1940s.

Ultrasound refers to acoustical waves above the range of human hearings (frequencies higher than 20 000 Hz). Although the same frequencies may be used both in medical ultrasound and in high-frequency radio systems (2 to 10 MHz), there is a distinguishing difference between them. Radio signals are electromagnetic waves, while medical ultrasound signals are acoustical. An ultrasonic wave is acoustical, which means that it requires a medium in which to propagate, while the electromagnetic signal can propagate in outer space, where no known medium exists.

The use of ultrasound in medical field can be divided into two major areas, therapeutic and diagnostic. The major difference between the two applications is the ultrasonic power at which the equipment operates. In therapeutic applications, the system operate at ultrasonic power levels of up to several watts per square centimeter while the diagnostic equipment operates at power levels of well below $100mW/cm^2$. The therapeutic equipment is designed to agitate the tissue to the level where thermal heating occurs in the tissue. For diagnostic purpose, on the other hand, as long as a sufficient amount of signal has returned for electronic processing, no additional energy is necessary. Since the absorption of ultrasound in tissue is proportional to the operating frequency which, in turn, is related to the desired resolution (ability to detect certain size target) the choice of ultrasonic power levels used is often dictated by the application.

The main attraction of ultrasound in medical modalities lies in its non-invasive character, externally applied, non-traumatic and also apparently safe at the acoustical intensities and duty cycles presently used in medical.

2.2 Therapeutic Ultrasound

For a given sound source, the higher the frequency, the less the sound beam diverges. Sound at audible frequencies appears to spread out in all directions, whereas ultrasound beam are well collimated. Provided that, ultrasound beams at frequencies greater than 800 kHz are sufficiently collimated to electively expose a limited target area for physical therapy treatment. At frequencies less than about 800kHz the ultrasound beam’s intensity levels is sufficiently low as to be outside the range for physical therapy treatment, but has been used at these low intensity levels for diagnostic procedures [8].

Absorption of sound, and therefore attenuation, increases as the frequency increases. Absorption occurs in part because of the internal friction in tissue that needs to be overcome in the passage of sound. The higher the frequency, the more rapidly the molecules are forced to move against this friction. As the absorption increases, there is less sound energy available to propagate through the tissue. At frequencies greater than 20 MHz, superficial absorption becomes so great that less than 1 percent of the sound penetrates beyond the first centimeter.

Therefore, for physical therapy applications, the frequency range is generally considered to be limited to frequencies within the range of about 800 kHz to about

3.3 MHz. However, the frequently most often used for physical therapy application is a frequency of about 1.0 MHz or 3.0 MHz because they offer good compromises between sufficiently deep penetration and adequate heating under customary exposure levels.

Sound waves can be produced as continuous wave or as pulsed wave. A pulsed wave is intermittently interrupted. Pulsed waves are further characterized by specifying the fraction of time the sound is present over one pulse period. This fraction is called the duty cycle and is calculated by dividing the pulse time on by the total time of a pulse period or similarly time on plus time off. Duty cycle for therapy machines, when in pulsed mode, range from about 5 percent to about 50 percent.

Intensity determined the strength of an ultrasound beam. It is the rate at which energy is delivered per unit area and is expressed in units of watts per square centimeter. Intensities employed in physical therapy are limited to the range of about 0.25 watts per square centimeter to about 3.00 watts per square centimeter.

In addition, for pulsed sound beam, the intensity of the beam will be zero when the beam is off and at its maximum during the pulse. Temporal average intensity of a beam is obtained by averaging the intensity over both the on and off periods. Hence, the temporal average intensity is decrease proportionally to the amount of time the sound is off. Since, the amount of heating depends on the temporal average intensity, thus less heating will occur even though the temporal peak intensity is unchanged.

Since the ultrasound beam is not uniform, some regions of the beam will be more intense than other regions. The measurement of intensity gives an average intensity and is referred to as the spatial average intensity. The World Health Organization limits the spatial average intensity to a maximum of 3 watt per square centimeter. On the other hand, intensities greater than 10 watt per square centimeter are used to destroy tissue surgically and temporal average intensities below 0.21 watt per square centimeter are used for diagnostic purposes [8].

2.3 Previous Patent on Ultrasound Therapy Products

Figure 2.1 below shows the block diagram of an ultrasound therapy machine invented by Maor et al in the patent number US 6 619 88 B2. [6]. Dates of this patent is on 2 September 2003.

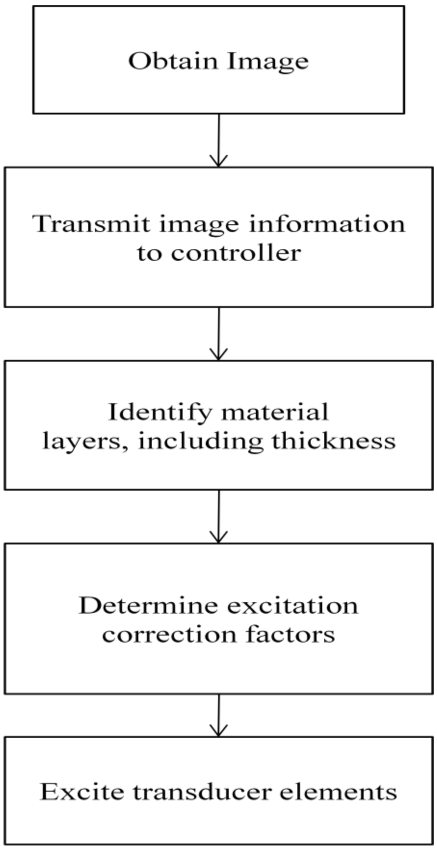


Figure 2.1 Ultrasound therapy

Figure 2.2 is it corresponding drawing of the system.

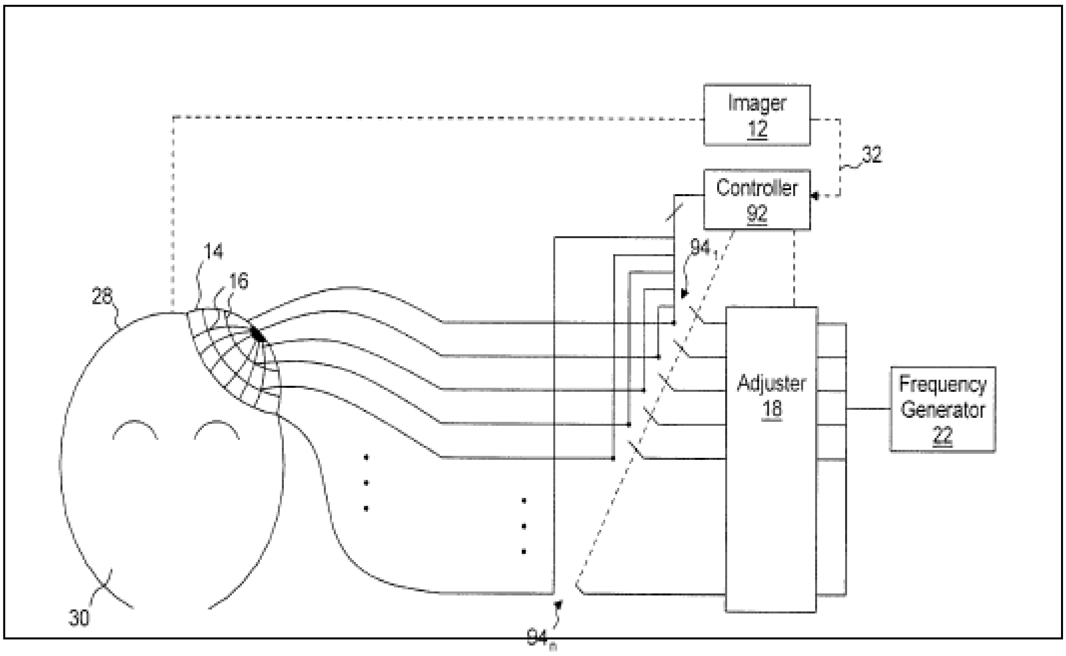


Figure 2.2 Drawing of an ultrasound therapy machine

This system is configured to deliver ultrasound energy in the range of 0.01 Mhz to 10 Mhz that is focused in the patient brain [6].

2.4 The Mechanisms of Action of Ultrasound

The mechanisms of action of ultrasound should be considered in terms of four categories. First is the thermal effect, which relates to the heat generated into the deeper tissues and especially the collagen, and the benefits derived from this. Second is the mechanical effect [3], which relates to the high-speed vibrations that act on the tissue just like a micro massage. Third is the cavitations effect. This refers to the production of countless microscopic droplets of oxygen from the vibration process. Fourth are the biological effects [1], which include blood vessel dilatation, improved blood flow and circulation, sonopheresis, improved lymph flow, muscle relaxation, reduced inflammation, and pain relief.

The technology of ultrasound revolves around the transmission of cyclic waves through the skin and the surrounding tissues. The ultrasonic machine sends millions of vibrations (1,000,000) per second into the deep tissues of the skin, breaking stubborn fat so that the fat can be decomposed. Ultrasound also encourages the production of collagen which irons out unsightly wrinkles and fat deposits. Ultrasound vibrating in a high frequency results in increased tissue stimulation, promotion of local metabolism, and excretion of skin waste [1].

As a result of millions of tiny sound waves being sent through the skin per second, frictional heat is created . In general, we can state that heat created is the product of the applied power intensity (I) in W/cm^2 and the absorption coefficient, cm^{-2} [7].

$$U_h = \alpha I$$

Where

U_h is the heat energy in watts (W)

α is the absorption coefficient cm^{-2}

I is the beam intensity in W/cm^2

This heat in the deep layers of the skin facilitates skin metabolism (collagen rejuvenation and reduction of fat deposits). This heat also causes the skin to excrete waste. Through the slight heat that is produced by the friction of the sound waves interacting with the deep tissue, the waste that rests just beneath the skin will be dissolved and the cellular fat shrunk. This all leads to a more attractive and younger appearance [1].

Ultrasonic waves cause liquid in the skin to form a vacuum, which is known as the hollow effect. In this vacuum state, gas rapidly vaporizes and emits numerous tiny bubbles. These bubbles initiate exothermic reactions or oxidation. This results in the decrease of damage particles. Ultrasonic waves promote pH changes. These changes include oxidation, reduced alkalinity, and changes in ionization and gelation [1].

In addition, biological effect is caused by the motion of the intracellular which is created by the vibrations of the membrane under the influence of the ultrasound waves. These movements often take the form of twisting action.

2.5 Temperature and Thermal Equilibrium

Temperature is a measure of the average heat or thermal energy of the particles in a substance. It is also the degree of hotness or coldness the can be measured using a thermometer. It's also a measure of how fast the atoms and molecules of a substance are moving.

Historically, there were two temperature scales (Fahrenheit and Celsius) that were produced as a practical convenience and neither of them have a deep physical meaning. The scale that is universally adopted as fundamental in physics is the Kelvin scale where "absolute zero" is defined as zero on the Kelvin scale. The increments in the Kelvin scale are called degrees and identically match the separation in Celsius degrees.

In order to calibrate thermometers between laboratories, there needs to be a specific temperature that can be reliably reproduced. One of these temperatures is called the triple-point of water, the temperature where water, ice, and water vapor coexist at atmospheric pressure. The triple-point of water is T_{tr} = 273.16 K. The relationship between degree Fahrenheit, Celsius and Kelvin are:

$$°F = 1.8° C + 32$$

$$°K = ° C + 273$$

It is observed that a higher temperature object which is in contact with a lower temperature object will transfer heat to the lower temperature object. The objects will approach the same temperature, and in the absence of loss to other objects, they will then maintain a constant temperature. They are then said to be in thermal equilibrium. Thermal equilibrium is the subject of the Zeroth Law of Thermodynamics.

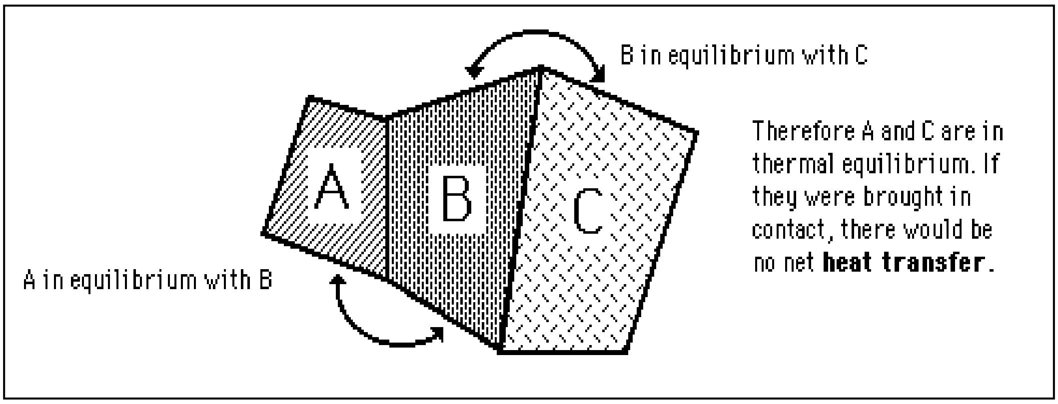


Figure 2.3 Thermal equilibrium

The "zeroth law" states that if two systems are at the same time in thermal equilibrium with a third system, they are in thermal equilibrium with each other. If A and C are in thermal equilibrium with B, then A is in thermal equilibrium with B. Practically this means that all three are at the same temperature, and it forms the basis for comparison of temperatures. It is so named because it logically precedes the First and Second Laws of Thermodynamics.

2.6 Thermal Effect of Ultrasound

Ultrasound is capable of producing thermal therapeutic effects. In 1987, Dyson suggested that the tissue must reach a temperature of 40°C to 45°C for at least five minutes to be therapeutic in nature. Experiments performed with nonperfused tissue demonstrated that ultrasound of frequency 1 MHz and intensity 1W/cm^2 could increase the tissue temperature at a rate of 0.86°C/min. Draper et al, Ashton et al and Chan et al measures the increased in muscle temperature during a ten minutes treatment with either 1 MHz or 3 MHz ultrasound by inserting thermistors to various depth within 5cm or less. The data they obtained shows that treatment with 1 MHz or 3 MHz ultrasound resulted in a time and dosage dependent increase in tissue temperature. However, the 3 MHz frequency increased tissue temperature at a faster rate than the 1 MHz frequency [16].

Ultrasound induce temperature rise varies with tissue properties such as absorption coefficient, density, perfusion, pulse duration, PRF (pulse repetition frequency) and beam or scanning configuration. The unique property of ultrasound induced temperature rise is that it is focal, which may not trigger systemic heat dissipating thermoregulatory mechanism.

The factors that affect tissue temperature rice include the ultrasound field parameters, the involved tissue characteristics, thermal conductivity of tissue and blood perfusion of tissue. Temperature rises are steeper in tissues that are poorly vascularizad such as tendon and fat and in tissues that conduct heat such as bone. Tissues adjacent to bone are particularly susceptible to heat increase via conduction. Biological tissue absorption is directly related to the protein content. Collagen are particularly has high absorption. Generally, absorption is greatest in mineralized bone followed by skin, tendon, spinal cord and finally brain, liver or kidney [16].

The primary ultrasound parameters to consider for thermal considerations include the wave form, either pulse or continuous, average and spatial intensity (W/cm^2), beam non-uniformity ratio (BNR), time of exposure, duty cycle and frequency. Generally, pulsed waves produce less heat than continuous while intensity parameters determine the total energy transferred to the tissue.

Draper et al demonstrated that 1MHz continuous ultrasound for 10 minutes 1.5 W/cm^2 produced a 5□C increase in the gastrocnemius muscle over 10 minutes at a depth of 3 cm without surface skin heating.

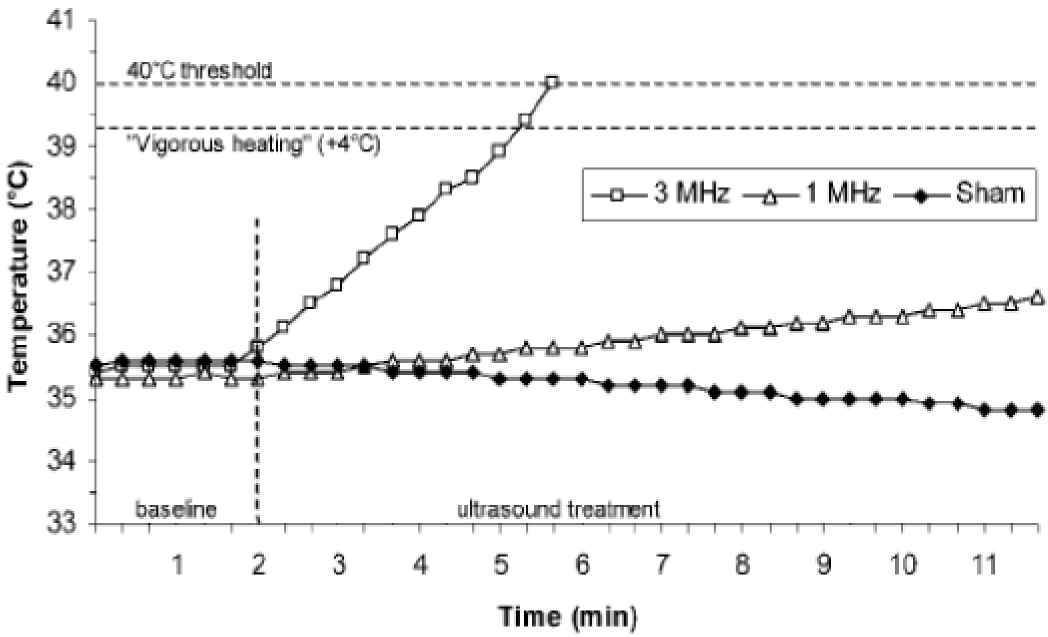


Figure 2.4 Tissue temperatures at 2.5 cm with 1.5 W/cm^2 ultrasound treatments

2.7 Comparison between Contact and Non-Contact Temperature Sensor

Table 2.1 below describes the difference between contact and non-contact temperature sensor in terms of measuring condition, measuring range, measuring accuracy and speed of the system.

Table 2.1 Comparison between contact and non-contact temperature sensor

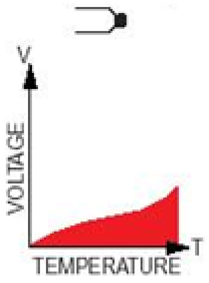
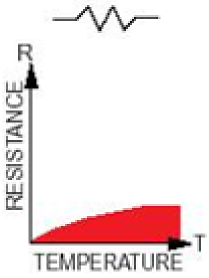
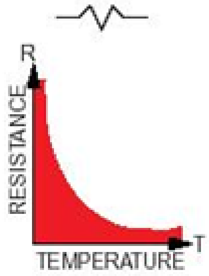
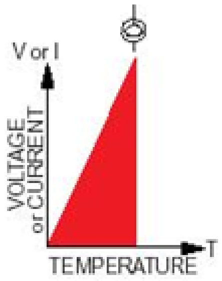
	Contact Methods	**Non-contact method**
Measuring conditions	▪ Measuring head contacts the measuring objects. ▪ No changes should be introduced in the temperature of the measured object when it is brought into contact with the	▪ Contact with the measuring object is indirect. Thus, the measuring object must be observable.

	measuring head.	
Measuring range	▪ Measurements made above 1200° C are difficult, but measurements below 1000° C are easily made.	▪ Large errors tend to occur when measurements are made below 1000° C. Measurements above 1000°C is easily made.
Measuring accuracy	▪ Generally, 0.5 to 1 %. ▪ 0.01% is possible, depending on the measuring conditions.	▪ Generally, around 20°C. ▪ 5 to 10°C at best.
Speed of response	▪ Generally slow about1 to 2 minutes. ▪ May take more than 1 hour in unfavourable conditions.	▪ Generally 2 to 3 seconds. ▪ Less than 10 seconds in the worst case.
Example	▪ Thermocouples, Resistance Thermo Detector (RTD), Thermistor, Glass Thermometer and Bimetallic.	▪ Infrared, Thermal Imagers, Optical Pyrometers

2.8 Comparison between 4 Types of Temperature Sensor

There are various temperature sensors available in market. The selection of sensor to be used for certain project are depends on the scope of the project. Table 2.2 below describes some of the difference in advantages and disadvantages between thermocouple, resistance thermo detector, thermistor and I.C sensor.

Table 2.2 Comparison between thermocouple, RTD, thermistor and I.C sensor

	Advantages	Disadvantages
Thermocouple 	• Self-powered • Simple • Rugged • Inexpensive • Wide Variety • Wide temperature range	• Non-linear • Low voltage • Reference Required • Least stable • Least sensitive
Resistance Thermo Detector (RTD) 	• Most stable • Most accurate • More linear than thermocouple	• Expensive • Current source required • Small resistance change • Low absolute resistance • Self-heating
Thermistor 	• High output • Fast • Twp-wire ohms measurement	• Non-linear • Limited temperature range • Fragile • Current source required • Self-heating
I.C. Sensor 	• Most linear • Highest output • Inexpensive	• Measurement range <200□C • Power supply required • Slow • Self-heating • Limited configurations

2.9 Temperature Sensor LM 35

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 does not require any external calibration or trimming to provide typical accuracies of (±1/4□C at room temperature and ±1/4□C over a full -55 to +150□C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 mA from its supply, it has very low self-heating, less than 0.1□C in still air. The LM35 is rated to operate over a -55 to a150□C temperature range. The LM35 series is available packaged in hermetic TO-46 transistor packages.

Features of LM 35:

I. Calibrated directly in □Celsius (Centigrade)
II. Linear a 10.0 mV/□C scale factor
III. 0.5□C accuracy guarantee (at a 25□C)
IV. Rated for full -55 to a150□C range
V. Suitable for remote applications
VI. Low cost due to wafer-level trimming
VII. Operates from 4 to 30 volts
VIII. Less than 60 mA current drain
IX. Low self-heating, 0.08□C in still air
X. Nonlinearity only ±1/4□C typical
XI. Low impedance output, 0.1 Ω for 1 mA load

Figure 2.5 Plastic package bottom view of LM 35

2.10 Microcontroller

A microcontroller is a small computer on a single integrated circuit consisting of a relatively simple CPU combined with support functions such as a crystal oscillator, timers, watchdog, serial and analog I/O. Program memory in the form of NOR flash or OTP ROM is often also included on chip, as well as a typically small reads/write memory. It is design for small applications compare to microprocessors and are used in automatically controlled products and devices, such as automobile engine, control systems, remote control, and many other applications.

Since embedded processors are usually used to control devices, they sometimes need to accept input from the device they are controlling. This is the purpose of the analog to digital converter. Since processors are built to interpret and process digital data, i.e 1s and 0s, they won't be able to do anything with the analog signals that may be being sent to it by a device. So the analog to digital converter is used to convert the incoming data into a form that the processor can recognize. There is also a digital to analog converter that allows the processor to send data to the device it is controlling.

2.11 RS232 Serial Port

RS232 is a popular communications protocol for connecting modems and data acquisition devices to computer. RS232 devices can be plugged straight into the computer's serial port (also known as the COM or Comms port) [18]. In serial communications, the terminal end PC is called Data Terminal Equipment or DTEs and the modem is called Data communication equipment or DCEs.

To obtain data from RS232 instrument and display it on PC, we need some software. There is version 4.3 of the Windmill RS232 software now available for free from their website [18].

RS stands for recommended standard. In the 60's a committee now known as the Electronic Industries Association developed an interface to connect to connect computer to terminals to modems. The standard defines the electrical and mechanical characteristics of the connection, including the function of the signals and handshake pins, the voltage levels and maximum bit rate. A nine pin D plug has become the standard fitting for the serial ports of PCs [18]. The pin connections used are shown in Figure 2.6 and the corresponding pin assignments are shown in Table 2.3.

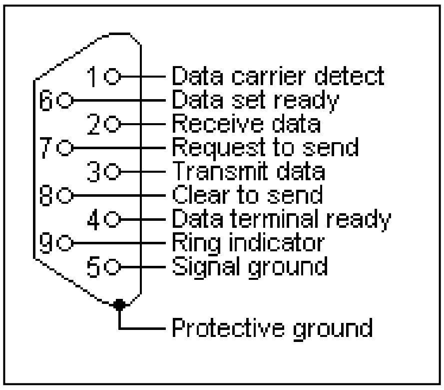


Figure 2.6 RS232 DB9 pinout

Table 2.3 RS232 pin assignments DB9 PC signal set

Pin 1	Input	DCD	Data Carrier Detect
Pin 2	Input	RXD	Received Data
Pin 3	Output	TXD	Transmitted Data
Pin 4	Output	DTR	Data Terminal Ready
Pin 5		Signal Ground	
Pin 6	Input	DSR	Data Set Ready
Pin 7	Output	RTS	Request To Send
Pin 8	Input	CTS	Clear To Send
Pin 9	Input	RI	Ring Indicator

The speed of RS232 communications is expressed in Baud. The maximum speed, according to the standard is 20000 Baud. However, modern equipment can operate much faster than this. No matter how fast or slow the connection, the maximum number of readings per second that it can take from the instrument depends on software. The length of the cable also plays a part in maximum speed. The longer the cable, the greater the cable's capacitance that results in the slower speed which can obtain accurate results [18].

2.12 Visual Basic 6.0

Visual Basic is a tool that allows the development of Windows (Graphic User Interface - GUI) application which the applications have a familiar appearance to the user.

Visual Basic is event-driven, meaning that the code remains idle until called upon to respond to some event (button pressing, menu selection, and etc). Visual Basic is governed by an event processor. Nothing happens until an event is detected. Once an event is detected, the code corresponding to that event (event procedure) is executed. Program control is then returned to the event processor [17].

These are some of the feature of the visual basic:

I. Full set of objects - 'draw' the application
II. Lots of icons and pictures for use
III. Response to mouse and keyboard actions
IV. Clipboard and printer access
V. Full array of mathematical, string handling, and graphics functions
VI. Can handle fixed and dynamic variable and control arrays
VII. Sequential and random access file support
VIII. Useful debugger and error-handling facilities
IX. Powerful database access tools
X. ActiveX support
XI. Package & Deployment Wizard makes distributing your applications simple

There are several items in visual basic that will be used in graphical user interface implementation. For example, form is the windows that will be create for user interface. Controls is the graphical features drawn on forms to allow user interaction (text boxes, labels, scroll bars, command buttons, etc.) (Forms and Controls are objects.) Every characteristic of a form or control is specified by a property. Example properties include names, captions, size, color, position, and contents. Visual Basic applies default properties. It can be change properties at design time or run time. Modules are the collection of general procedures, variable declarations, and constant definitions used by application [17].

There are three primary steps involved in building a Visual Basic application:

1. Draw the user interface.
2. Assign properties to controls.
3. Attach code to controls.

Six windows appear upon start Visual Basic. The Main Window consists of the title bar, menu bar, and toolbar. The title bar indicates the project name, the current Visual Basic operating mode, and the current form. The menu bar has drop-down menus from which you control the operation of the Visual Basic environment. The toolbar has buttons that provide shortcuts to some of the menu options. The main window also shows the location of the current form relative to the upper left corner of the screen and the width and length of the current form [17].

The Form Window is central to developing Visual Basic applications. It is where the application is drawn.

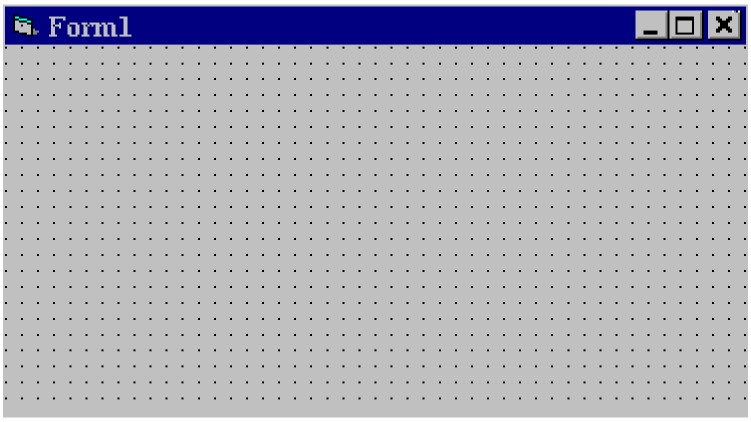


Figure 2.7 Form

The toolbox contains the selection menu for controls used in the application.

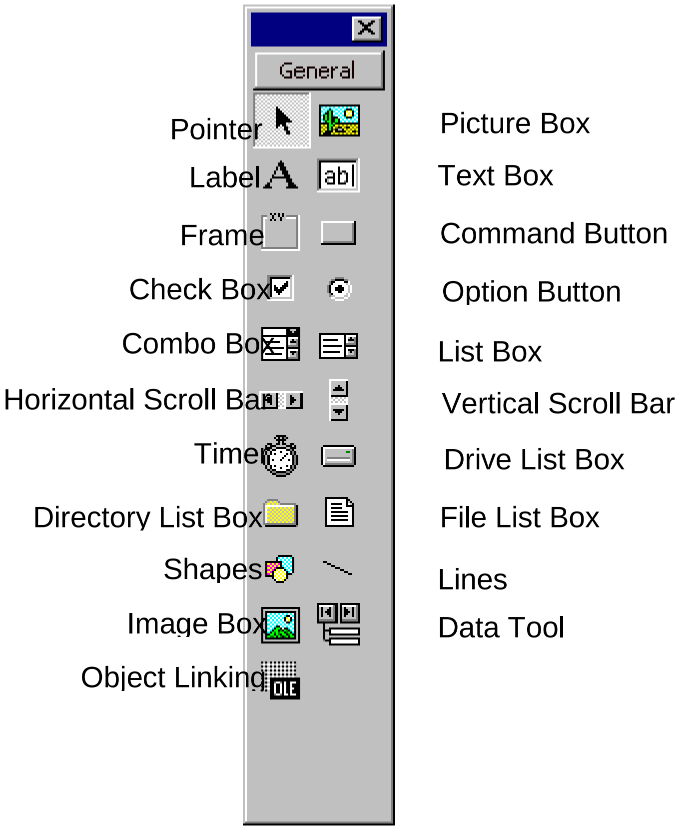


Figure 2.8 Toolbox

The Properties Window is used to establish initial property values for objects. The drop-down box at the top of the window lists all objects in the current form. Two views are available, alphabetic and categorized. Under this box are the available properties for the currently selected object.

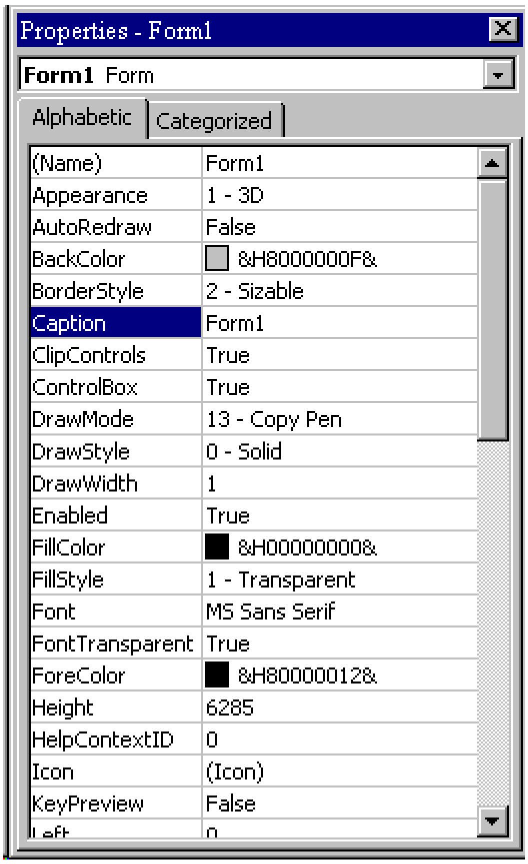


Figure 2.9 Properties

The Form Layout Window shows where (upon program execution) the form will be displayed relative to monitor's screen:

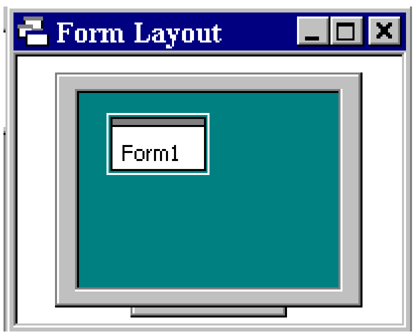


Figure 2.10 Form layout

The Project Window displays a list of all forms and modules making up the application. A view of the Form or Code windows (window containing the actual Basic coding) also can be obtained from the Project window.

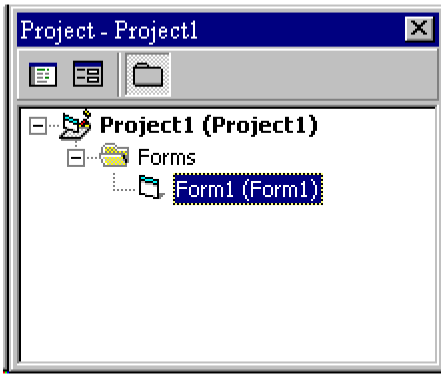


Figure 2.11 Project window

The user interface is 'drawn' in the form window. There are two ways to place controls on a form. First, double-click the tool in the toolbox and it is created with a default size on the form. You can then move it or resize it. The second way is click the tool in the toolbox, then move the mouse pointer to the form window. The cursor changes to a crosshair. Place the crosshair at the upper left corner of where you want the control to be, press the left mouse button and hold it down while dragging the cursor toward the lower right corner. When you release the mouse button, the control is drawn [17].

CHAPTER 3

DESIGN AND IMPLEMENTATION

3.1 Introduction

This chapter describes the design and implementation for the temperature monitoring system for an ultrasound therapy machine. This system implementation functions as one of the important safety feature in the ultrasound therapy machine. This project included the implementation of the hardware and software. The required range of temperature monitoring is from 35□C to 55□C. Meanwhile, the resolution of this system is needed at 1□C.

Figure 3.1 below shows the simplified block diagram of a smart ultrasound therapy machine. This ultrasound therapy machine will have three main important subsystems which includes ultrasound therapy waveform transmitter, ultrasound receiver monitoring system and temperature monitoring system. However, this report is specifically focus on the temperature monitoring design and implementation for this system.

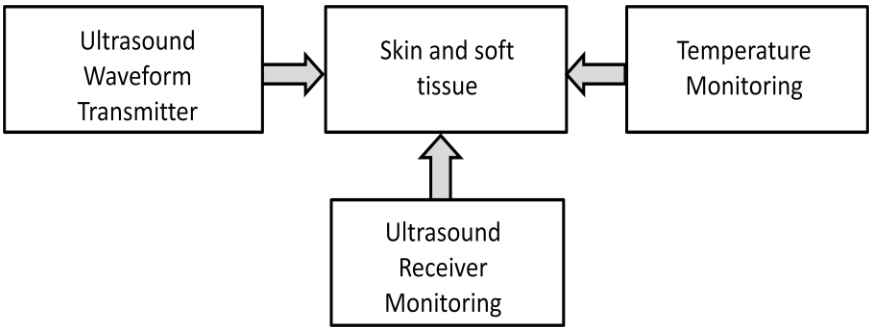


Figure 3.1 Simplified block diagram of a smart ultrasound therapy machine

Below is the detail block diagram for a smart ultrasound therapy machine. This block diagram shows the detail compartment for every single block diagram from Figure 3.1.

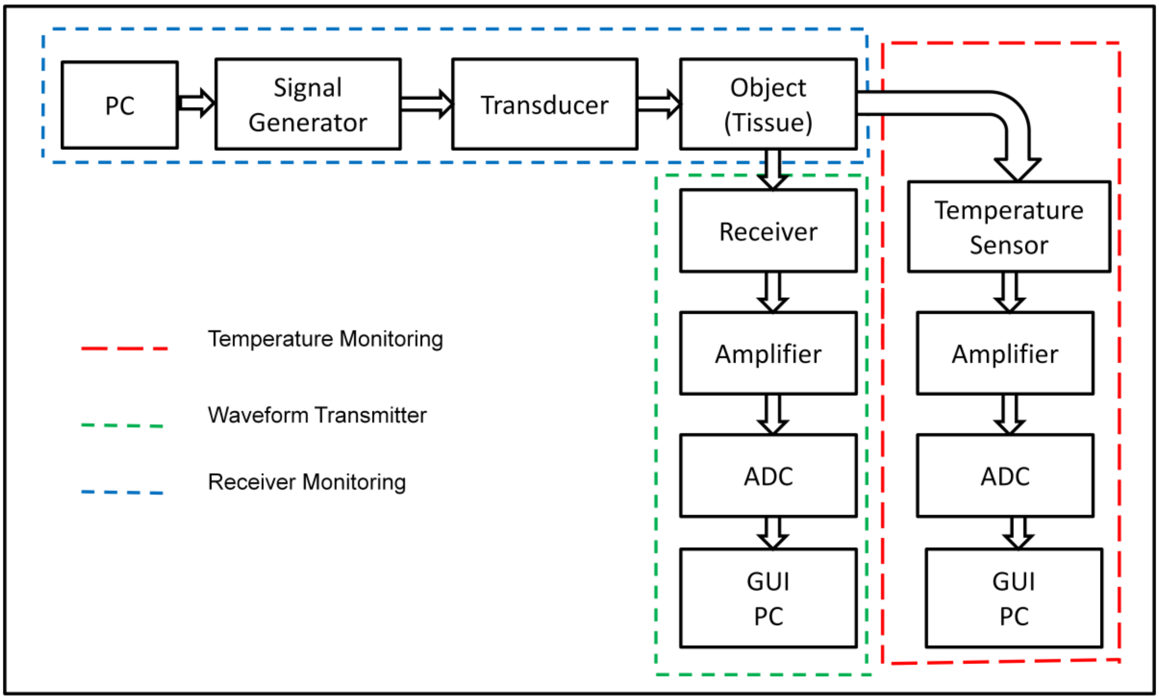


Figure 3.2 Detailed block diagram of a smart ultrasound therapy machine

3.2 Temperature Monitoring System for Ultrasound Therapy Machine

Figure 3.2 above shows the connection between the three subsystems and how it will be integrated. However, this project reports only about the temperature monitoring system for this ultrasound therapy machine.

Temperature monitoring system block diagram is as shown in Figure 3.3 below.

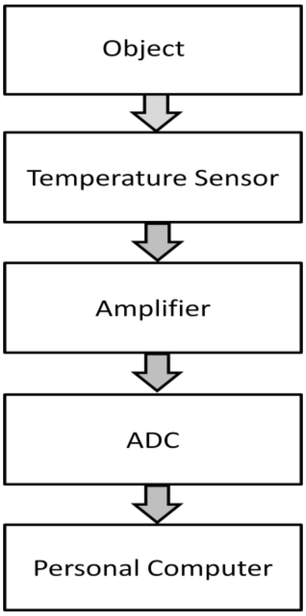


Figure 3.3 Block diagram of the temperature monitoring system

Basically in this project of temperature monitoring system for ultrasound therapy machine, there are hardware and software to be implement. As seen from the block diagram above, the hardware that needs to be implement are temperature sensor circuit, amplifier and analog to digital circuit.

In addition, in order to display the temperature on personal computer, software coding for analog to digital converter that read the analog temperature measured by the sensor and converts it to digital number has been developed in PIC C programming. To make this project more user friendly, graphical user interface that display the temperature on personal computer have been implement in Visual Basic 6.0 environment.

3.3 Hardware Implementation

This section will discuss about the components and circuit that have been developed for this project such as temperature sensor circuit, embedded analog to digital converter in PIC16F877A microcontroller and RS232 serial input output port.

3.3.1 Temperature Sensor Circuit

Figure 3.4 below shows the schematic diagram of the temperature sensor circuit that has been developed in Multisim 8.

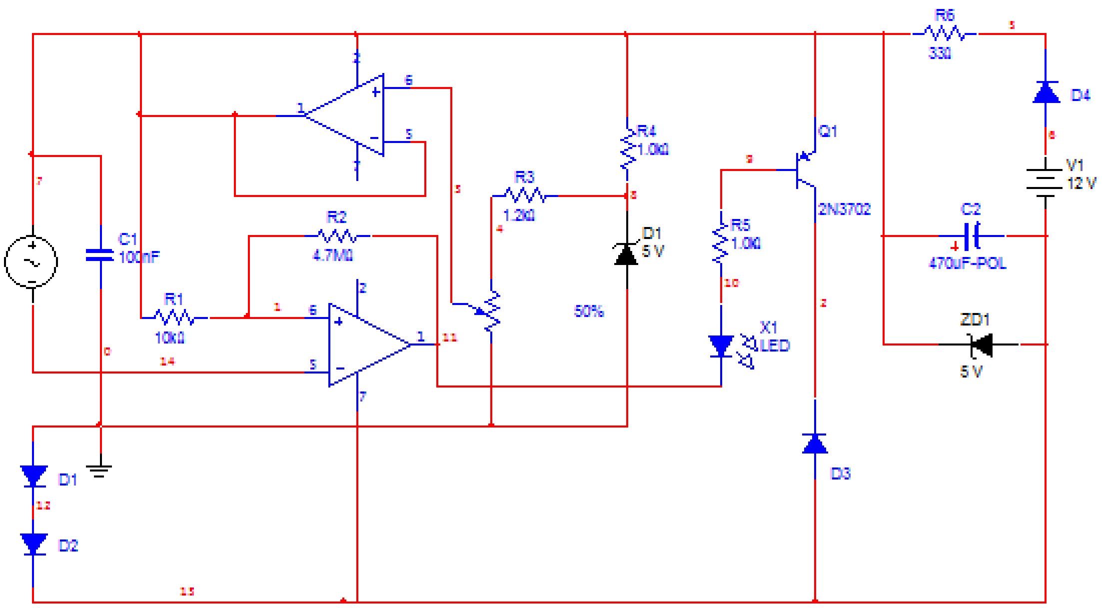


Figure 3.4 Circuit diagram of temperature sensor circuit

The listings of components used to build the temperature sensor circuit are shown in Table 3.1. The heart of this circuit is the IC LM 35 temperature sensor.

Table 3.1 Components that build up temperature sensor circuit

Number	Components	Description
1.	LM 35	Precision centigrade temperature sensor
2.	TL 431	Precision voltage reference
3.	LM 358	Dual single supply op-amp
4.	LED1	5mm LED
5.	Q1	General purpose PNP transistor
6.	D1,D2	1N4148 silicon diodes
7.	D3,D4	1N4002 rectifier diodes
8.	ZD1	Zener diode, 12V, 400mW
9.	Preset (trim pot)	2.2K
10.	Resistor	• R1 = 10K • R3 = 4.7M • R3 = 1.2K • R4 = 1K • R5 = 1K • R6 = 33Ω
11.	Capacitors	• C1 = 0.1μF ceramic cap • C2 = 470μF electrolytic cap
12.	Miniature relay	DC12V DPDT

Figure 3.5 below shows the picture of the temperature sensor circuit that have been developed and used in this project.

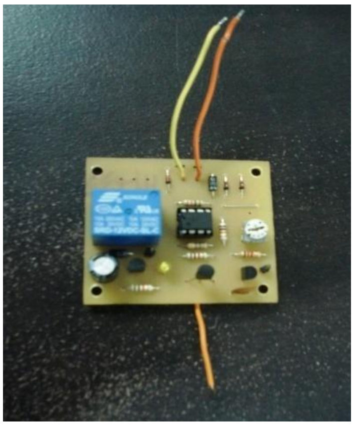


Figure 3.5 Temperature sensor circuit

The input (heat) of this circuit is sensed by LM 35 temperature sensor. This temperature sensor is factory calibrated in the Celsius scale with a linear degree and voltage correlation. The output voltage at pin 2 of LM 35 change with temperature from -550mV (-55□C) to 1500mV (150□C).

3.3.2 Embedded ADC in PIC16F877A Microcontroller

This project requires resolution of 0.1□C. So, the suitable ADC should be the one of 10 bit. In this project, embedded ADC in PIC16F877A is used. Figure 3.6 below shows the image and the pin diagram of the microcontroller used.

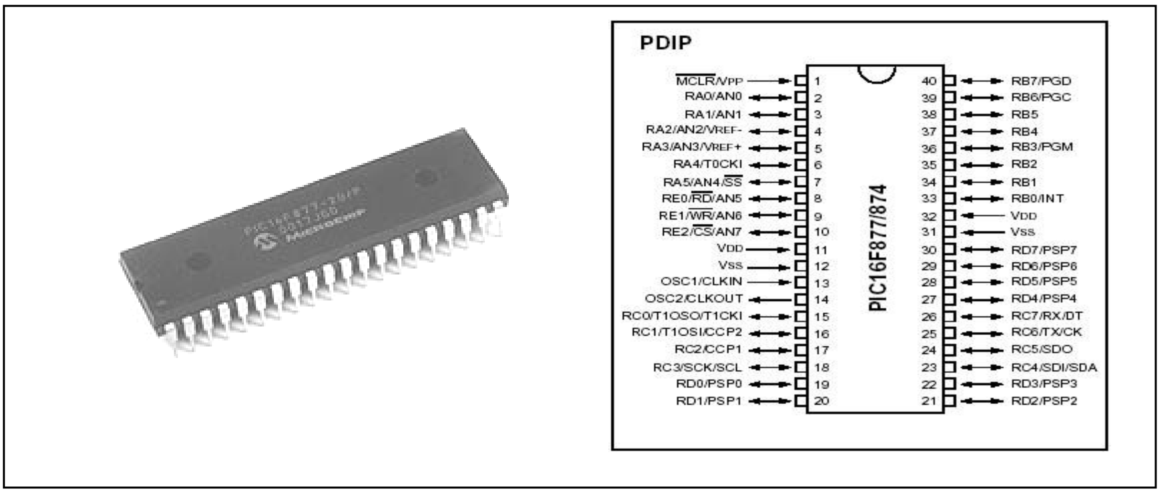


Figure 3.6 Image and pin diagram of PIC16F877A

Figure 3.7 below shows the microcontroller circuit and its connection with the temperature sensor circuit and RS232. The input from temperature sensor circuit is connected to AN0 (pin 2) and ground (pin 14) is connected to the ground of the temperature sensor circuit. Output from the ADC is connected to personal computer through RS232 serial port.

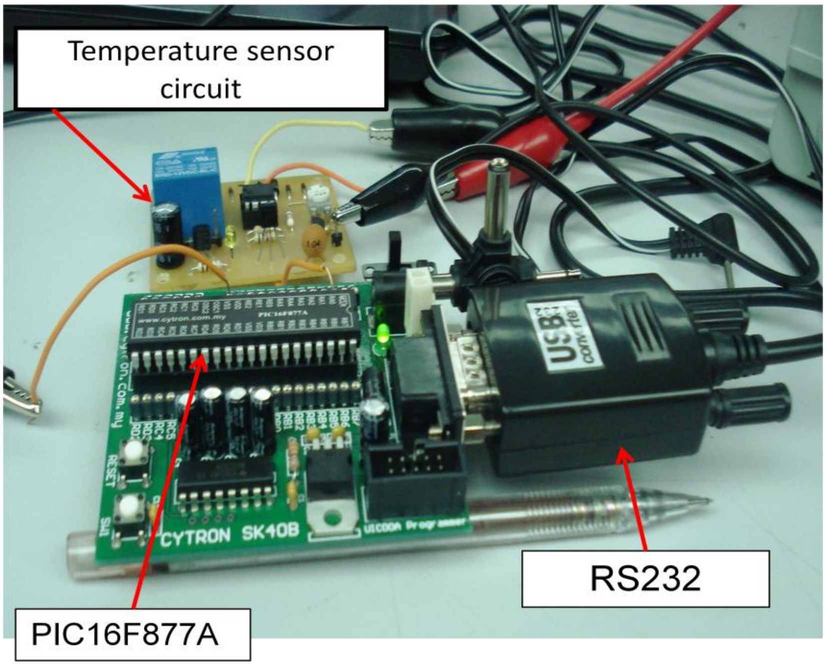


Figure 3.7 Embedded ADC in PIC16F877A connected to PC through RS232

3.4 Software Implementation

For software implementation, PIC C Compiler is used to write and compile the program of the microcontroller. Meanwhile, PICkit 2 v2.40 is used to load the hex file from the PIC C to the microcontroller. Other than that, Visual Basic 6.0 is used for programming the user interface and monitoring the start temperature and time, stop temperature and time and also the ultrasound therapy application duration.

3.4.1 Algorithm for Analog to Digital Converter

Figure 3.8 below shows the flow chart of how to setup ADC and read the value of ADC from the PIC 16F877A Microcontroller.

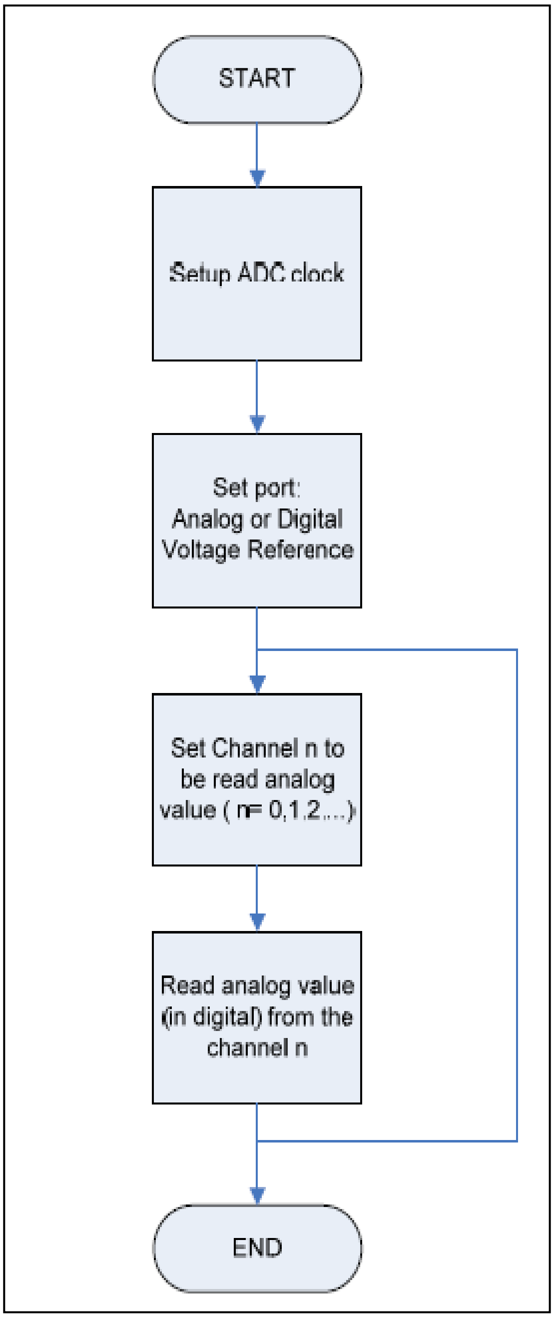


Figure 3.8 Flow chart of ADC

3.4.2 Programming in PIC C Compiler

First, the equation those relate the output voltage from temperature sensor circuit had been determined. This equation is required to convert the output voltage from pin 2 of LM 35 to temperature in □C. The equation is:

Temperature = 100*Output Voltage

```
void main()
{
float V;//T;
   setup_adc_ports(AN0);
   setup_adc(ADC_CLOCK_INTERNAL);
   setup_psp(PSP_DISABLED);
   setup_spi(SPI_SS_DISABLED);
   setup_timer_0(RTCC_INTERNAL|RTCC_DIV_1);
   setup_timer_1(T1_DISABLED);
   setup_timer_2(T2_DISABLED,0,1);
   setup_comparator(NC_NC_NC_NC);
   setup_vref(FALSE);

   // TODO: USER CODE!!
V=read_adc();
V=(V*1/51);
printf("Voltage = %6.4f\n\r",V);
T=100*V;
printf("Temperature= %3.1f\n\r degree Celcius",T);
putc(0x0D);
putc(0x0A);
}
```

Figure 3.9 Programming for ADC in PIC C Compiler

Figure 3.8 below shows the corresponding hex file for the ADC programming.

```
#include <16F877A.h>
#device adc=10

#FUSES NOWDT                    //No Watch Dog Timer
#FUSES HS                       //High speed Osc (> 4mhz)
#FUSES NOPUT                    //No Power Up Timer
#FUSES NOPROTECT                //Code not protected from reading
#FUSES NODEBUG                  //No Debug mode for ICD
#FUSES NOBROWNOUT               //No brownout reset
#FUSES NOLVP                    //No low voltage prgming, B3(PIC16) or
B5(PIC18) used for I/O
#FUSES NOCPD                    //No EE protection
#FUSES WRT_50%                  //Lower half of Program Memory is Write
Protected

#use delay(clock=20000000)
#use rs232(baud=9600,parity=N,xmit=PIN_C6,rcv=PIN_C7,bits=8
```

Figure 3.10 Hex file in PIC C

3.4.3 Algorithm and Programming in Visual Basic 6.0

Graphical user interface for this project have been developed in Visual Basic 6.0. The purpose of this graphical user interface is to display the temperature and duration of the ultrasound therapy application. The flow of this GUI is shown in Figure 3.11 below.

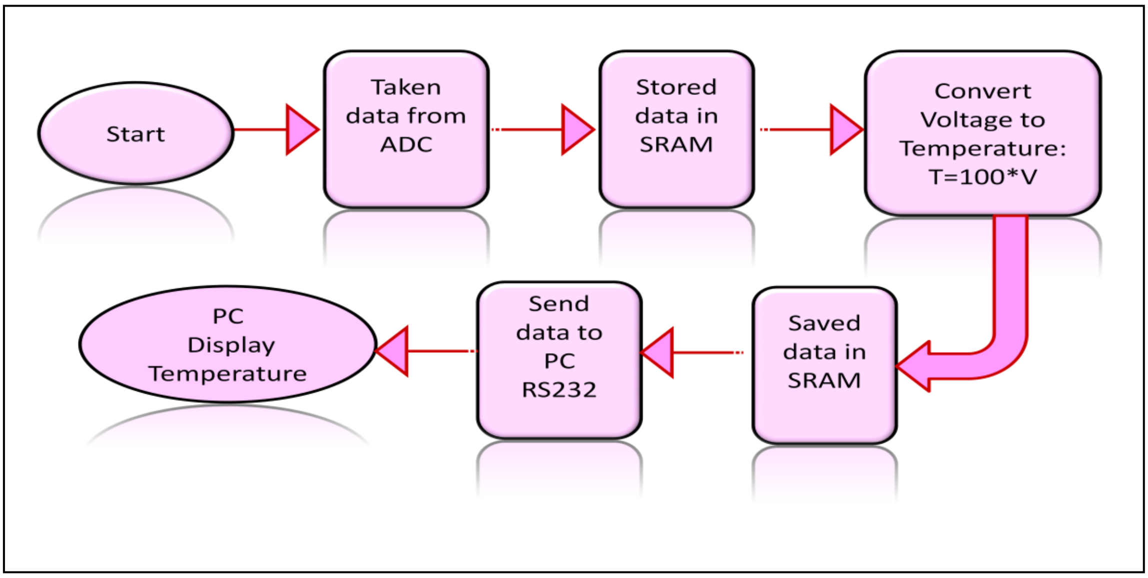


Figure 3.11 Flows of GUI programming

Figure 3.12 shows the form, properties, form layout and toolbox in visual basic 6.0. Command button, label, text box and many more tools are select from the toolbox on the left. Double clicking on the desired tool and it will appear on the form. The properties of each box can be choose to change from the properties

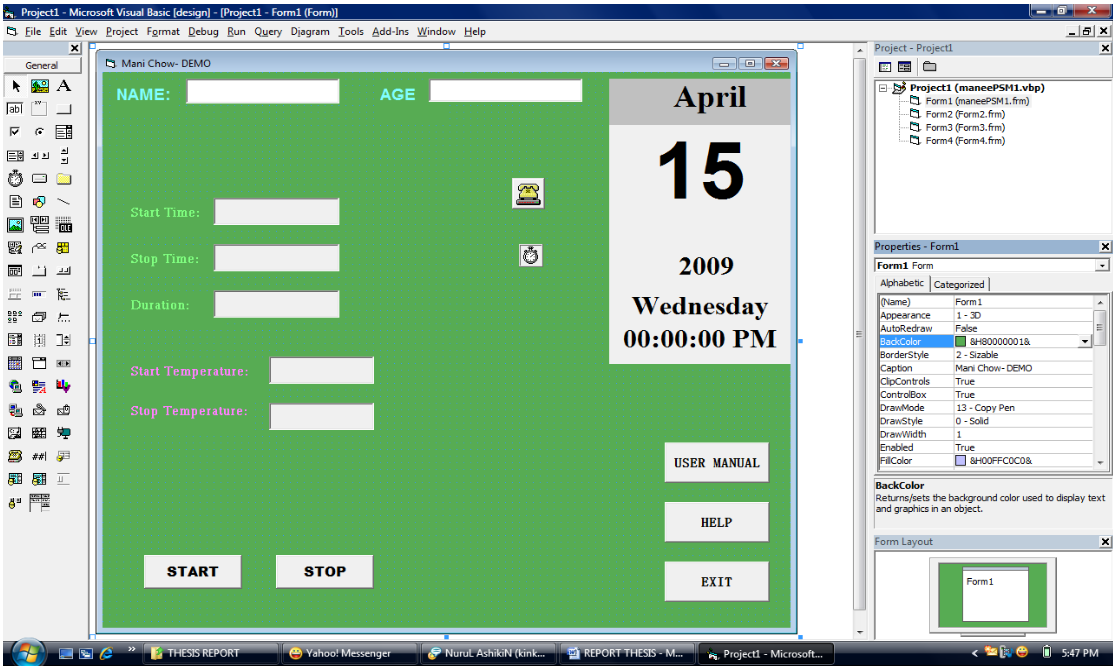


Figure 3.12 Visual basic 6.0

3.4.3.1 Forms

There are four main forms in this graphical user interface. The first form is the introduction form, which is shown in Figure 3.13 below. This form appear when the user start running the visual basic program. In only contains the information about the title of this project, presenter, supervisor and a start command button with caption START DEMO.

Figure 3.13 Introduction form

Once the START DEMO button is pressed, form of Figure 3.14 will be shown. This is the user manual form. This form will give information to the user on how to use this graphical user interface. To proceed to the main form where to display the temperature, the user must click on the next button.

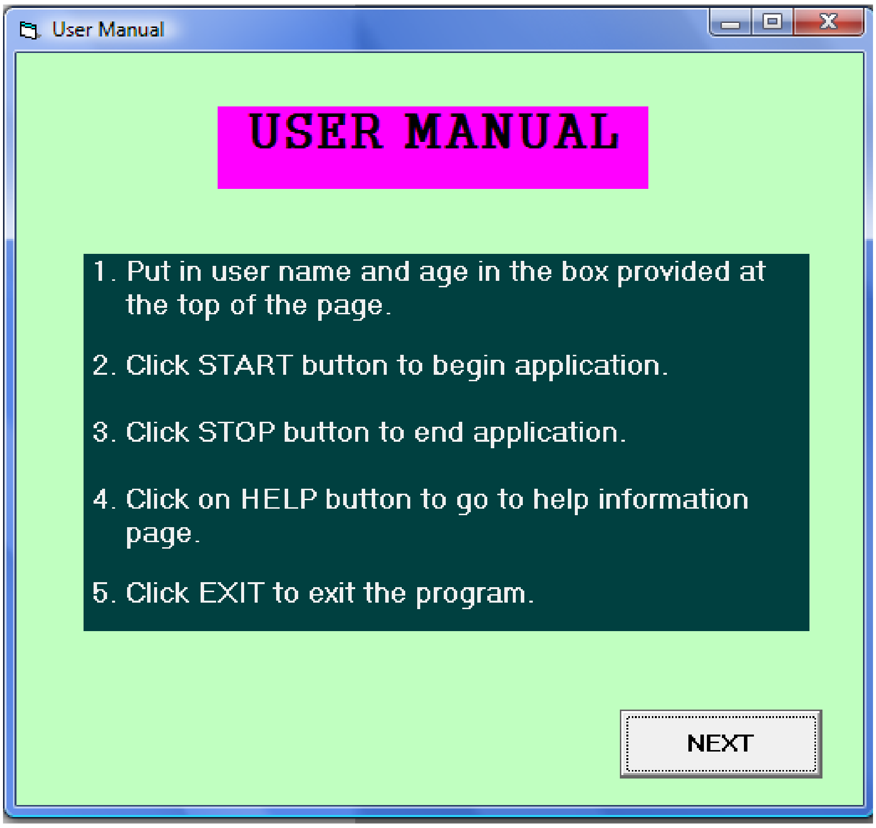


Figure 3.14 Users manual form

After the user had click the next button as in form 2 of Figure 3.14 above, the user will be redirected to the main from as shown in Figure 3.15 below. There was a calendar at the right top this form which shows the current date and time. The users have the option to put in their personal particular such as name and age. First the user must click on the corresponding box to activate it and then type in their personal particular.

The START button is used to start the application. Once the START button is clicked, start time and temperature will be shown. Stop time and temperature will be shown when the user click on the STOP button to stop the application. USER MANUAL and HELP box will redirect the user back to the user manual and help form. In this form, MS Comm is needed to be place here because this GUI gets their input from RS232 port. Other than that, a timer also had been included here because it counts the time interval that the data being sent to the GUI.

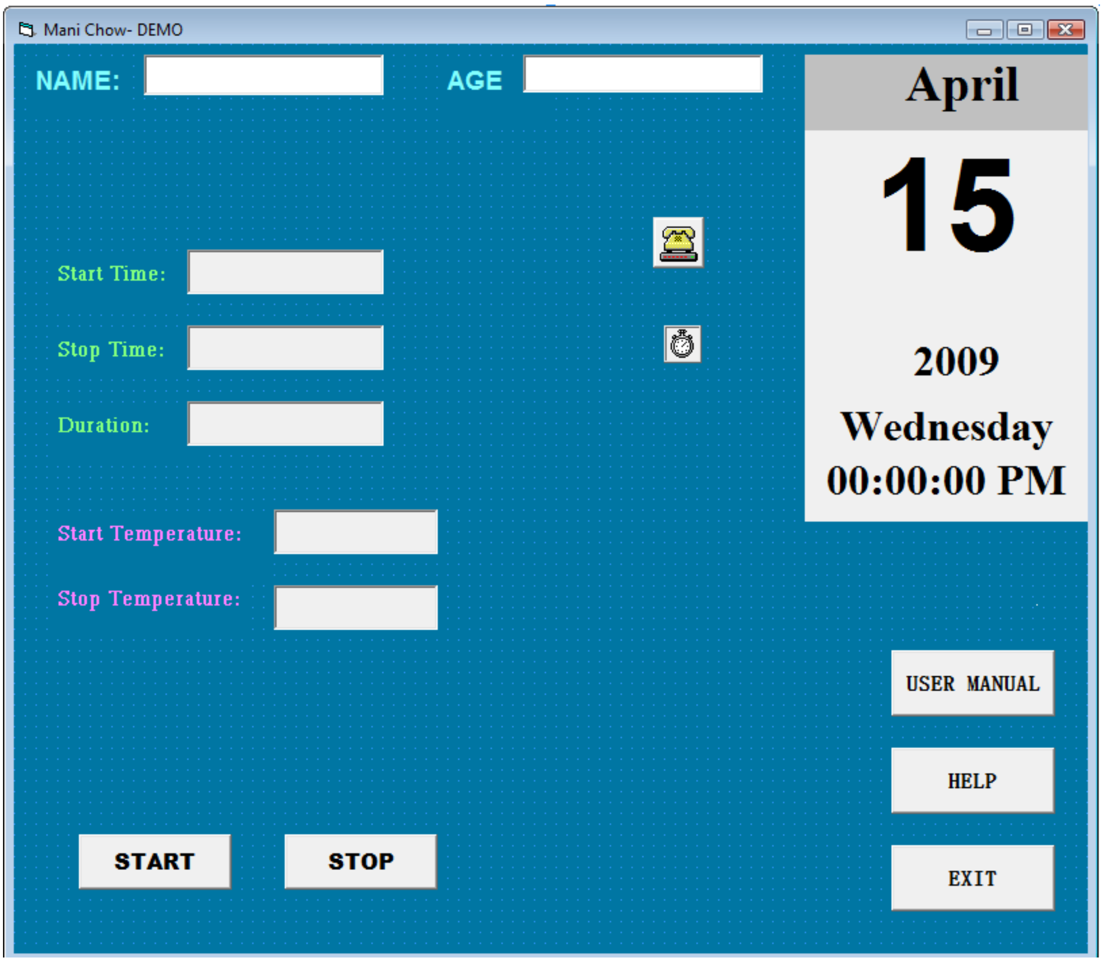


Figure 3.15 Main form display temperature

Figure 3.16 below shows the help information form. In this form is included the information that the user might needed when using this GUI application. BACK button will redirect the user back to main form.

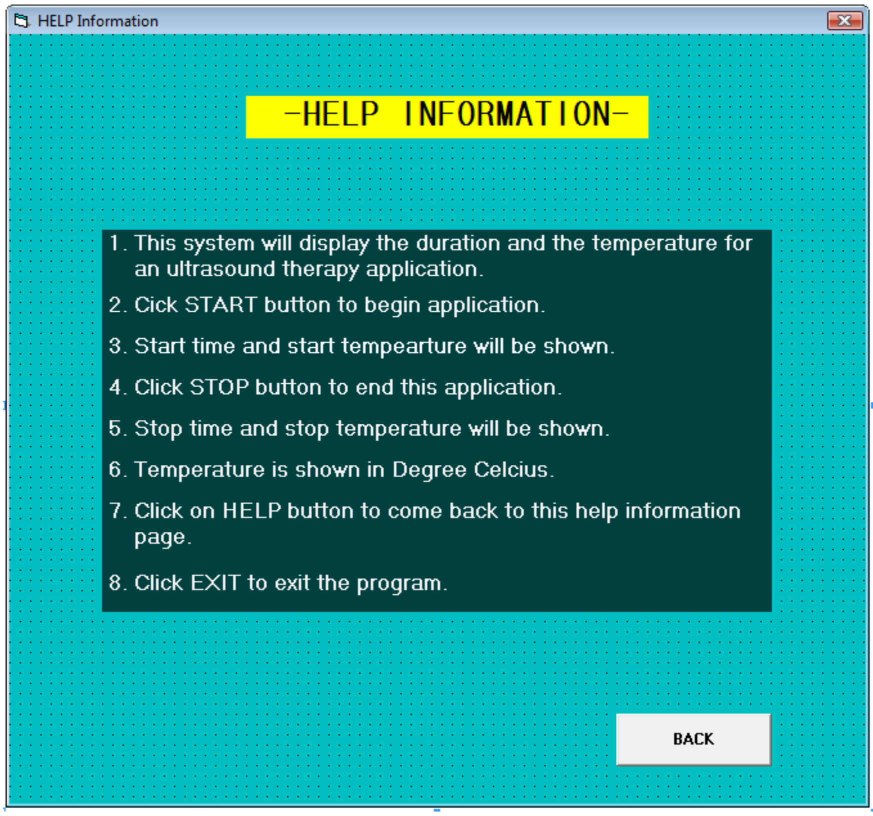


Figure 3.16 Help form

3.4.3.2 GUI Source Code

All the variables used must be declared as in the Figure 3.17 below:

```
Dim StartTime As Variant
Dim StopTime As Variant
Dim ElapsedTime As Variant
Dim TempF As Variant
Dim TempC As Variant
Dim InData As String
```

Figure 3.17 Variable declaration

This part of report will describe about the source code implemented for graphical user interface.

```
Private Sub cmdStart_Click()
    'Message box confirm the user whether start or cancel start
    begin = MsgBox("Start a new session?", vbOKCancel + vbQuestion
_vbDefaultButton1, "Start")
```

Figure 3.18 Message box coding

This part of source code is used to prompt the user confirmation about starting the application. A message box as below appears:

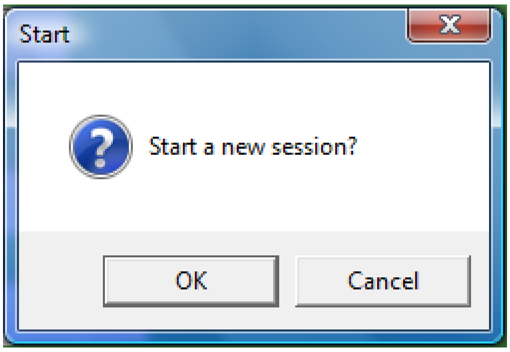


Figure 3.19 Start Message Box

If the user select yes, then start time and the current temperature sensed will be displayed on the main form.

```
If begin = vbOK Then
'Start a new session Establish and print starting time
StartTime = Now
lblStart_TimeD.Caption = Format(StartTime, "hh:mm:ss")
lblStop_TimeD.Caption = ""
lblElapsed_TD.Caption = ""
End If
```

Figure 3.20 Source code for start time

```
'Get input from MSComm and display temperature during start
MSComm1.InputLen = 10
If MSComm1.InBufferCount > 10 Then
InData = MSComm1.Input
MSComm1.InBufferCount = 0
lblTemp1.Caption = InData
End If
```

Figure 3.21 Source code for start temperature

The following source code is used to display the calendar. Local variables declaration is used here in line 3.

```
1.   'Time and Date (Calendar) Display
2.   Private Sub Timer1_Timer()
3.   Dim Today As Variant
4.   Today = Now
5.   lblDay.Caption = Format(Today, "dddd")
6.   lblMonth.Caption = Format(Today, "mmmm")
7.   lblYear.Caption = Format(Today, "yyyy")
8.   lblNumber.Caption = Format(Today, "d")
9.   lblTime.Caption = Format(Today, "h:mm:ss ampm")
10.  End Sub
```

Figure 3.22 Source code for calendar

3.5 Problem and Solution in Implementation

The actual plan for this system is using infrared temperature sensor. However, because of time limitation, the sensor had been replaced with semiconductor integrated circuit sensor. Infrared temperature sensor is hard to find in local market.

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

Some experiments had been conducted throughout semester one. First experiment was to find the relationship between voltage and power of an ultrasound therapy machine. The effects of the distances from the transmitter to the receiver with the output voltage were observed. Then, the data collected were plotted on graph for further analyzed. After that, there was another experiment to find out the relationship of the thermal effect with the time of ultrasound therapy irradiation. The data obtained were then plotted on graph for further analyzed.

4.2 Experiment 1: Determine Relationship of Power Supply and Voltage of an Ultrasound Therapy Devices

Figure 4.1 shows the experimental setup to determine the relationship between power supply and the output voltage of a machine for fat removal with the application of ultrasound. Tx represent the ultrasound transmitter and Rx represent the ultrasound receiver. The oscilloscope will show the ultrasound waveform and the corresponding voltage will be read from the amplitude of the waveform. There are three condition tested in this experiment which is differing by the three different medium between the space of the transmitter and the receiver as shown in Figure 4.1. The three conditions were:

i. Transmitted the ultrasound through transmission gel

ii. Transmitted the ultrasound through water

iii. No specific transmission medium (very near transmission through air)

The power of the machine for fat removal is changed from 1W to 8W. Five measurement of voltage are taken for each power level. For this experiment, there are two different waveform used, continuous and pulse.

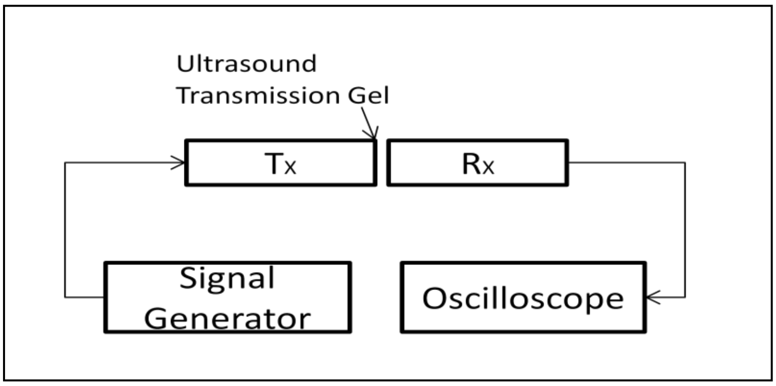


Figure 4.1 Experimental setup to determine the relationship between power and voltage

4.2.1 Procedures

1. The experiment was set up as Figure 4.1.
2. Choose continuous waveform from the machine for fat removal.
3. Start with power 1W.
4. Take measurement of output voltage from oscilloscope.
5. Increase the power one unit until 8W.
6. Repeat step 3, step 4 and step 5 until five measurements were taken for each power level.
7. The corresponding voltage and power is recorded in table.
8. Three graph of voltage versus power containing five series of measurement each were plotted.
9. Repeat step 3, 4,5,6,7 and 8 for pulse waveform.

4.2.2 Experimental Result Analysis

The data for continuous waveform were recorded in Table 4.1, Table 4.3 and Table 4.5 and the corresponding graph of voltage versus power were plotted in Figure 4.2, Figure 4.4 and Figure 4.6 respectively.

On the other hand, Table 4.2, Table 4.5 and Table 4.6 record the data for pulse waveform. Graph of output voltage versus power supply were plotted in Figure 4.3, Figure 4.5 and Figure 4.7.

4.2.2.1 Transmitted the Ultrasound through Transmission Gel for Continuous Waveform.

Table 4.1 Relationship of power supply and output voltage

Power (Watt)	Trial 1 (Volt)	Trial 2 (Volt)	Trial 3 (Volt)	Trial 4 (Volt)	Trial 5 (Volt)
1	20	15	5	10	14
2	20	17	10	9	23
3	20	15	10	10	24
4	15	15	15	10	31
5	20	18	20	20	35
6	22	20	23	20	17
7	25	39	23	23	12
8	30	23	25	22	14

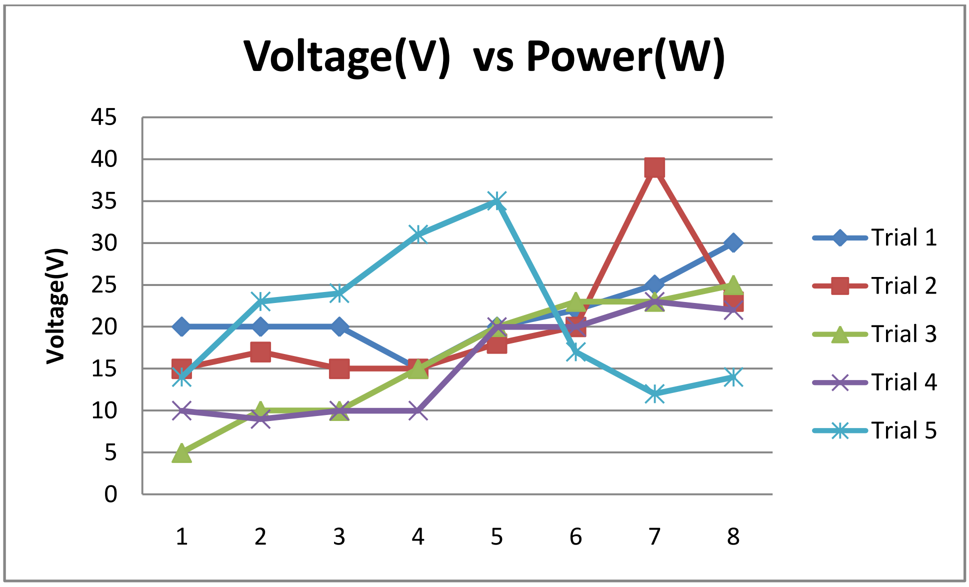


Figure 4.2 Graph of voltage versus power supply

4.2.2.2 Transmitted the Ultrasound through Transmission Gel for Pulse Waveform.

Table 4.2 Relationship of power supply and output voltage

Power (Watt)	Trial 1 (Volt)	Trial 2 (Volt)	Trial 3 (Volt)	Trial 4 (Volt)	Trial 5 (Volt)
1	15	6	11	23	35
2	14	10	16	19	33
3	11	12	11	17	35
4	10	11	7	26	39
5	12	18	23	18	27
6	20	17	22	21	22
7	11	20	24	19	28
8	20	18	21	20	26

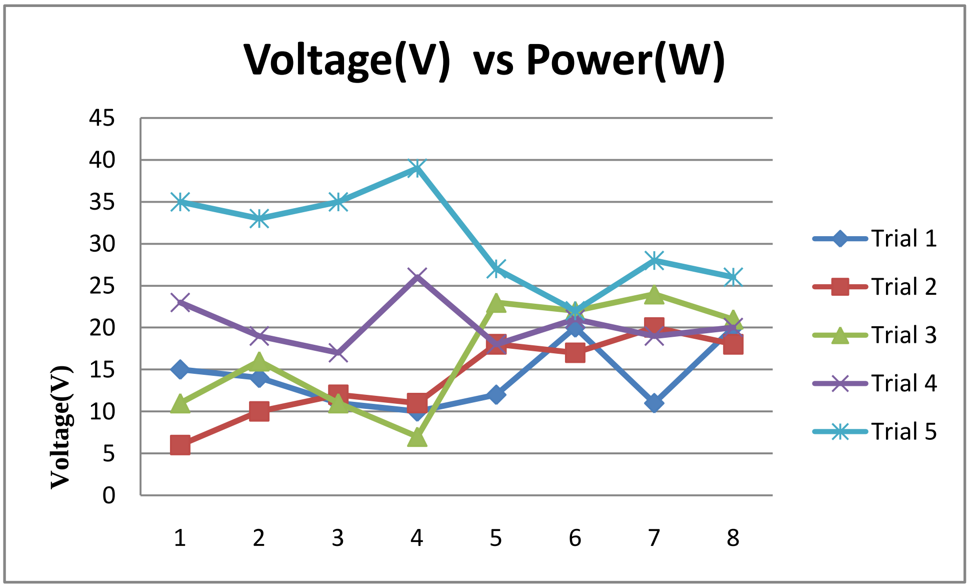


Figure 4.3 Graph of voltage versus power supply

4.2.2.3 Transmitted the Ultrasound through Water for Continuous Waveform.

Table 4.3 Relationship of power supply and output voltage

Power (Watt)	Trial 1 (Volt)	Trial 2 (Volt)	Trial 3 (Volt)	Trial 4 (Volt)	Trial 5 (Volt)
1	1.88	1.88	1.92	2.00	1.92
2	1.92	2.04	1.96	2.04	1.96
3	2.00	2.12	2.00	2.08	2.00
4	2.04	2.20	2.04	2.12	2.08
5	2.12	2.16	2.12	2.16	2.12
6	2.08	2.24	2.16	2.20	2.16
7	2.12	2.28	2.24	2.24	2.20
8	2.16	2.28	2.28	2.24	2.24

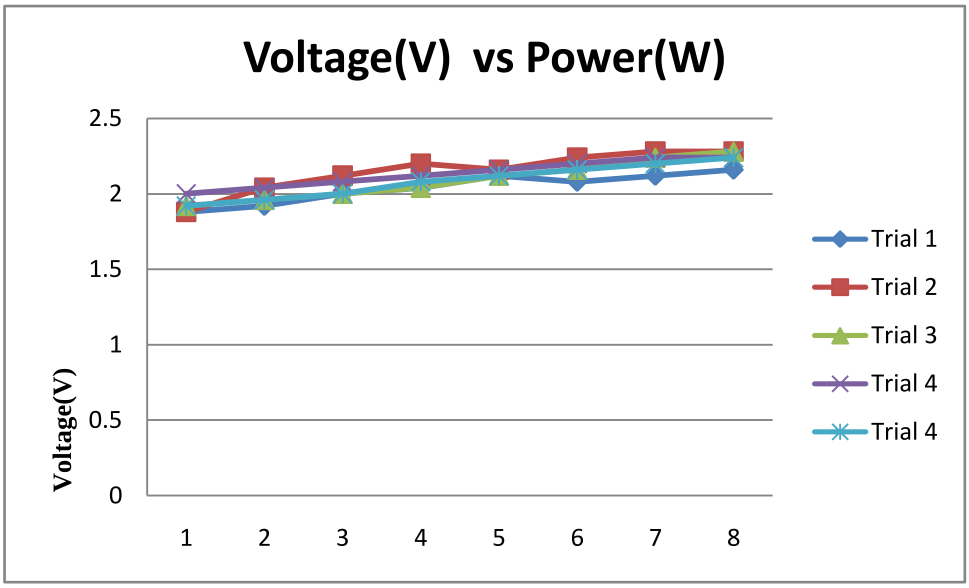


Figure 4.4 Graph of voltage versus power supply

4.2.2.4 Transmitted the Ultrasound through Water for Pulse Waveform.

Table 4.4 Relationship of power supply and output voltage

Power (Watt)	Trial 1 (Volt)	Trial 2 (Volt)	Trial 3 (Volt)	Trial 4 (Volt)	Trial 5 (Volt)
1	1.88	1.88	1.84	1.84	1.8
2	1.96	1.96	1.92	1.88	1.96
3	2.04	1.96	1.96	1.92	2
4	2.04	2	2.04	1.96	2.04
5	2.08	2.04	2.08	2	2.08
6	2.12	2.08	2.12	2.08	2.12
7	2.2	2.12	2.16	2.16	2.16
8	2.2	2.16	2.24	2.2	2.24

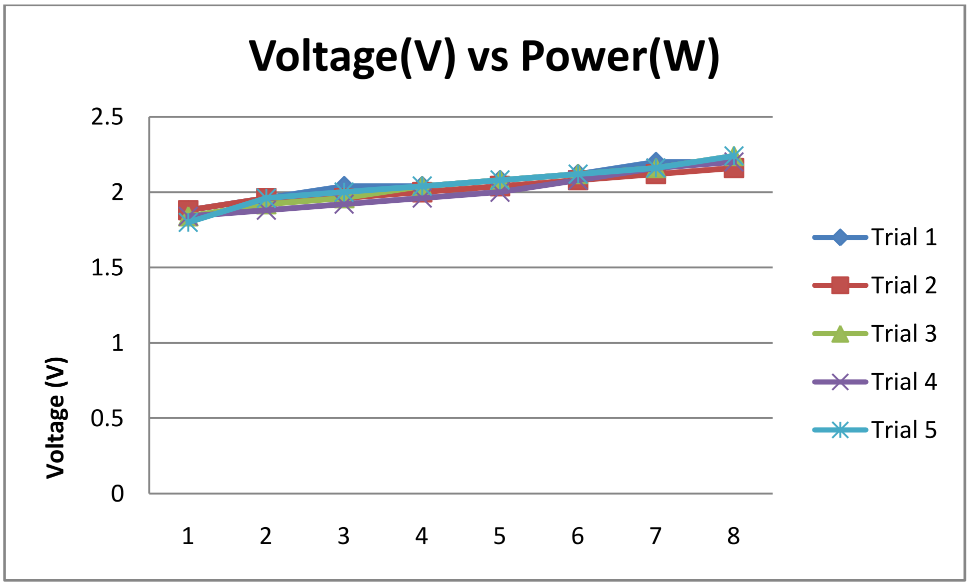


Figure 4.5 Graph of voltage versus power supply

4.2.2.5 No Specific Transmission Medium for Continuous Waveform

Table 4.5 Relationship of power supply and output voltage

Power (Watt)	Trial 1 (Volt)	Trial 2 (Volt)	Trial 3 (Volt)	Trial 4 (Volt)	Trial 5 (Volt)
1	0.58	0.6	0.6	0.6	0.68
2	0.6	0.62	0.66	0.62	0.72
3	0.6	0.64	0.68	0.66	0.76
4	0.62	0.64	0.64	0.72	0.76
5	0.68	0.66	0.68	0.74	0.78
6	0.64	0.68	0.7	0.76	0.8
7	0.68	0.72	0.72	0.8	0.84
8	0.72	0.74	0.74	0.86	0.86

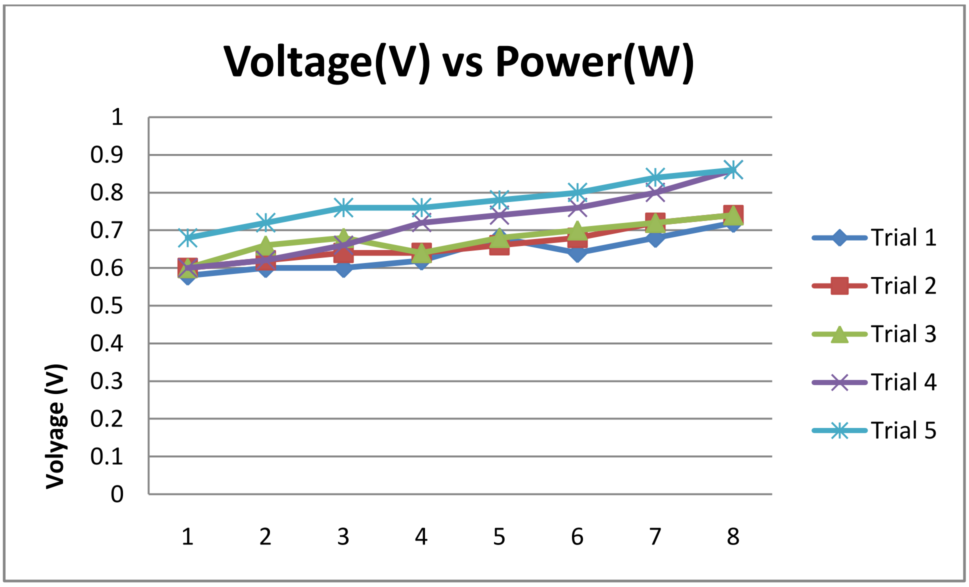


Figure 4.6 Graph of voltage versus power supply

4.2.2.6 No Specific Transmission Medium for Pulse Waveform.

Table 4.6 Relationship of power supply and output voltage

Power (Watt)	Trial 1 (Volt)	Trial 2 (Volt)	Trial 3 (Volt)	Trial 4 (Volt)	Trial 5 (Volt)
1	0.58	0.58	0.66	0.52	0.66
2	0.6	0.58	0.68	0.6	0.7
3	0.7	0.6	0.7	0.62	0.74
4	0.74	0.7	0.72	0.76	0.78
5	0.78	0.78	0.74	0.8	0.78
6	0.78	0.8	0.8	0.8	0.8
7	0.82	0.8	0.82	0.82	0.82
8	0.84	0.84	0.82	0.82	0.84

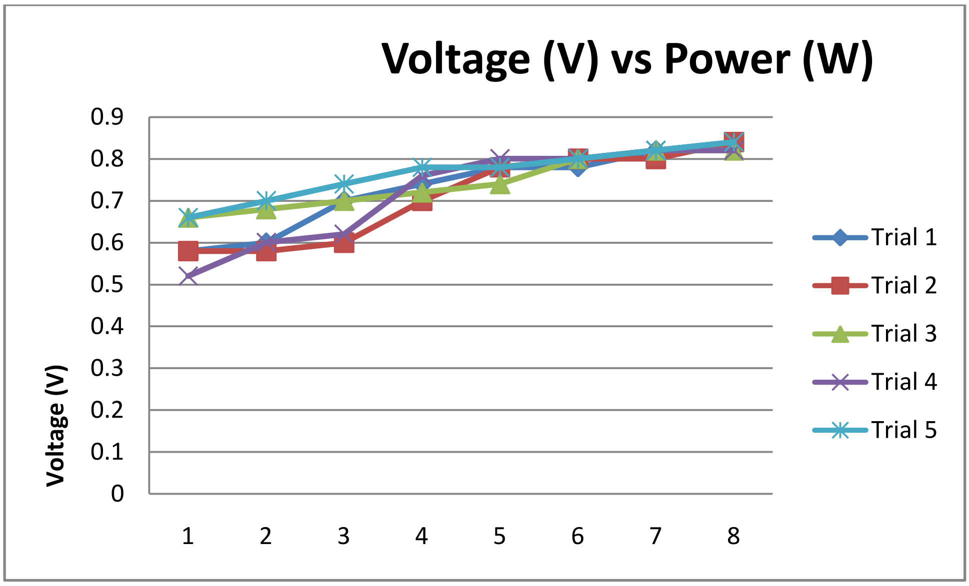


Figure 4.7 Graph of voltage versus power supply

4.2.3 Result Discussion

There are similarity shown in the graph of Figure 4.4, Figure 4.5, Figure 4.6, and Figure 4.7. The increment in power is causing linear increment in voltage. But, the graph of Figure 4.2 and Figure 4.3 shows that the increment in power does not cause linear increment in voltage.

This phenomenon can be explained by Figure 4.8 below. The amplitude of the graph represents the voltage while the horizontal axis represents the distance between the transmitter and receiver. If the transmitter and receiver are placed very near to each other, it will cause the non linear relationship of output voltage and supply power to the ultrasound machine. However, as the distance in more far, it will result in linear relationship between voltage and power.

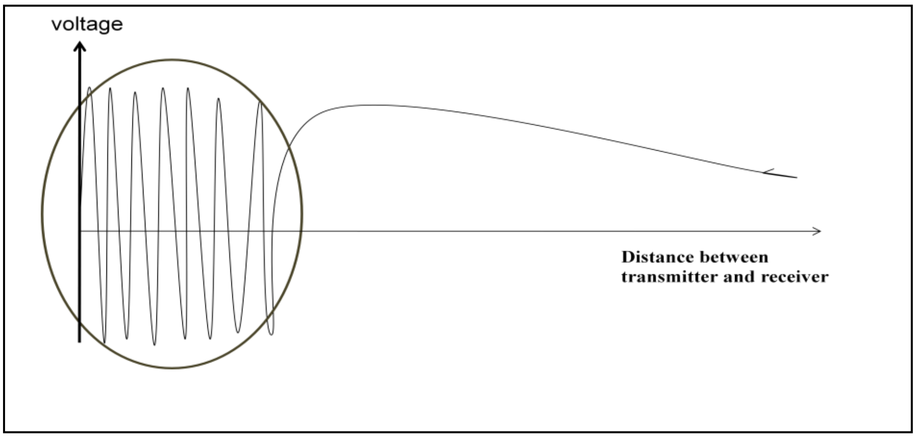


Figure 4.8 Distance between transmitter and receiver of ultrasound and the output voltage

4.3 Experiment 2: Determine the Thermal Effect with Time of an Ultrasound Therapy.

The experiment set up was as in Figure 4.9. Thermometer is used to measure the temperature of the fat inside the tank. The temperature reading was taken every 5 minutes after the continuous irradiation of ultrasound. Ultrasound was irradiated from a fat removal machine. The ultrasound frequency used was 1MHz and power is select to 8Watts.

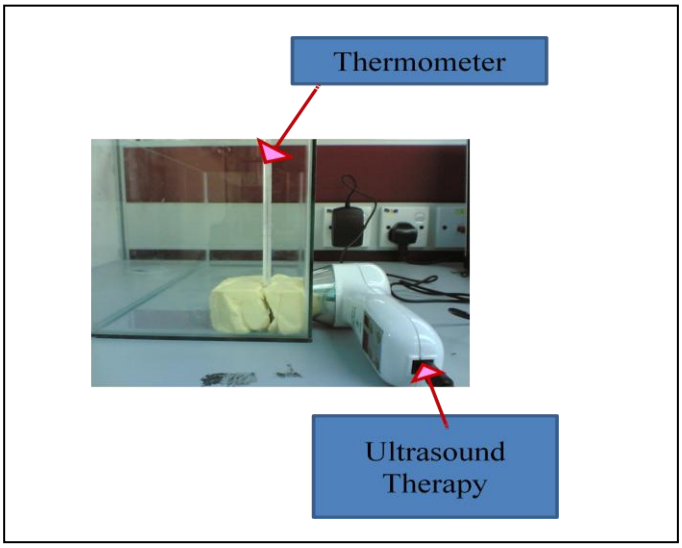


Figure 4.9 Experimental setup

4.3.1 Procedures

1. Set up the experiment as Figure 4.9.
2. Irradiate ultrasound towards the tank containing fat.
3. Take the temperature reading every 5 minutes until 120 minutes.
4. Record the data in a table.
5. Plotted the graph from the data obtained.

4.3.2 Experimental Result Analysis

The data obtained were recorded in Table 4.7 and the corresponding graph was plotted as shown in Figure 4.10.

Table 4.7 Relationship of ultrasound therapy irradiation time and temperature

Time (minutes)	Temperature (°C)
5	18
10	18
15	18
20	19
25	19
30	20
35	20
40	20
45	21
50	21
55	22
60	22
65	23
70	23
75	24
80	24
85	25
90	25
95	25
100	25
105	26
110	26
115	26
120	27

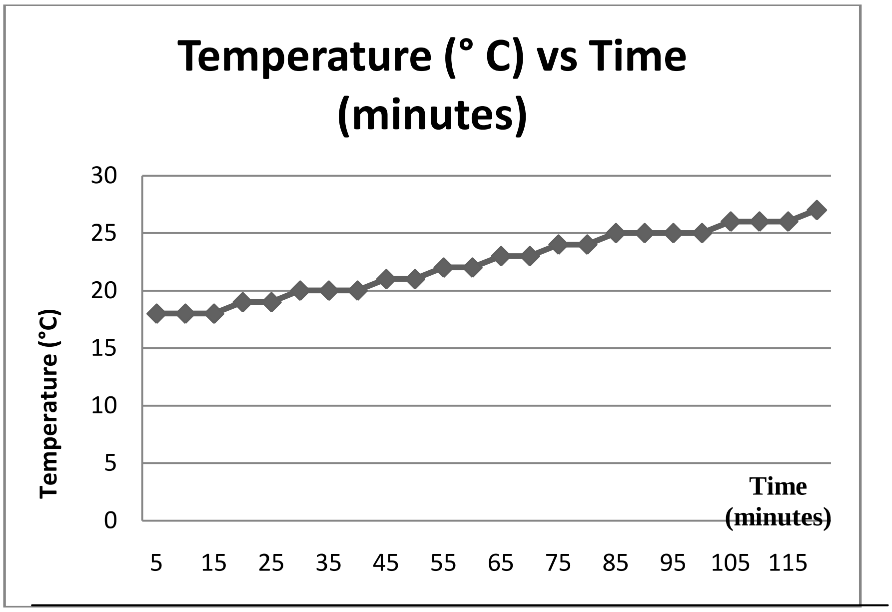


Figure 4.10 Graph of Temperature versus Time

4.3.3 Result Discussion

From the graph of Figure 4.10, it shows that the temperature is increasing as the time of ultrasound irradiation longer. This means that ultrasound irradiation produce heat. This result is significant because it is one of the factors that help in fat destruction.

4.4 Experiment 3: Comparison between system measurement and thermometer measurement.

This experiment was set up to determine the accuracy of the temperature monitoring system.

4.4.1 Procedures

1. Fill in a tank with water.
2. Take the temperature reading outside the tank using thermometer.
3. Take temperature measurement using the system implement in this project.
4. Change the test water for 5 set of reading.
5. Record the data in table.
6. Plot graph.
7. Make comparison.

4.4.2 Experimental Result

Table 4.8 Test Measurement Results

Test	Thermometer (□C)	System (□C)	Accuracy (%)
1	25	25.7	97.20
2	30	29.2	97.30
3	35	34.5	98.57
4	40	40.3	99.99
5	45	45.4	99.99

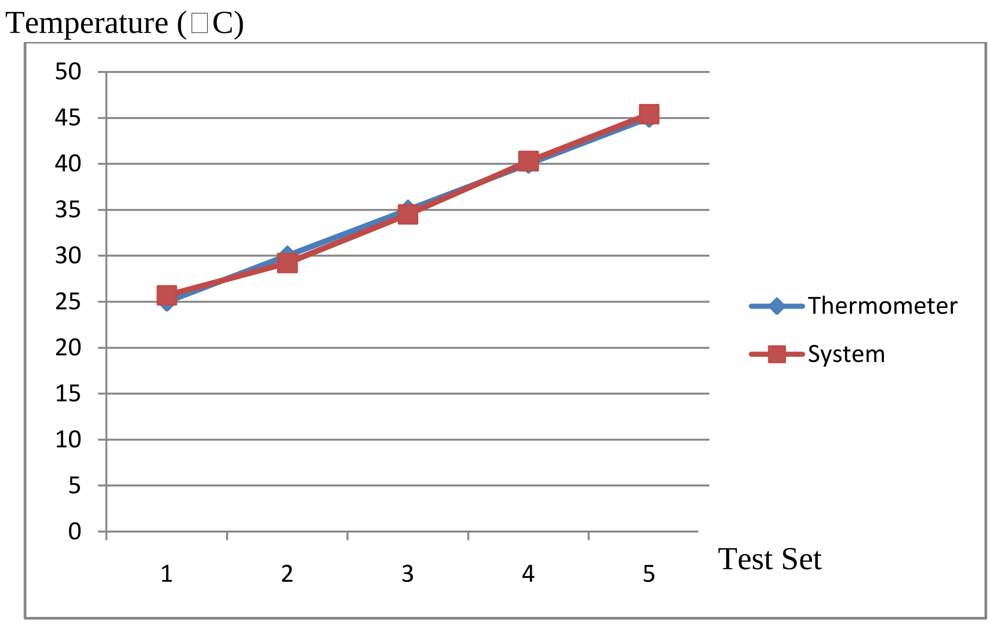


Figure 4.11 Graph of measurement between thermometer and system

4.4.3 Discussion

Accuracy calculation:

$$\text{Accuracy (\%)} = \frac{|\ \text{Thermometer (□C)} - \text{System (□C)}\ |}{\text{Thermometer (□C)}}$$

From Table 4.8, it is found out that most of the temperature measurement accuracies are more 95%. Thus, this system is reliable.

Graph of Figure 4.11 shows that the temperature for both measurement are linear.

4.5 Limitation

Only contact temperature measurement is allowable for this system. The whole system is large and cannot keep in the casing of the ultrasound therapy transducer.

4.6 Possible Application and Market

Figure 4.12 below shows the possible application of this system. From the figure, the temperature sensor is attached in the casing of the ultrasound therapy transducer.

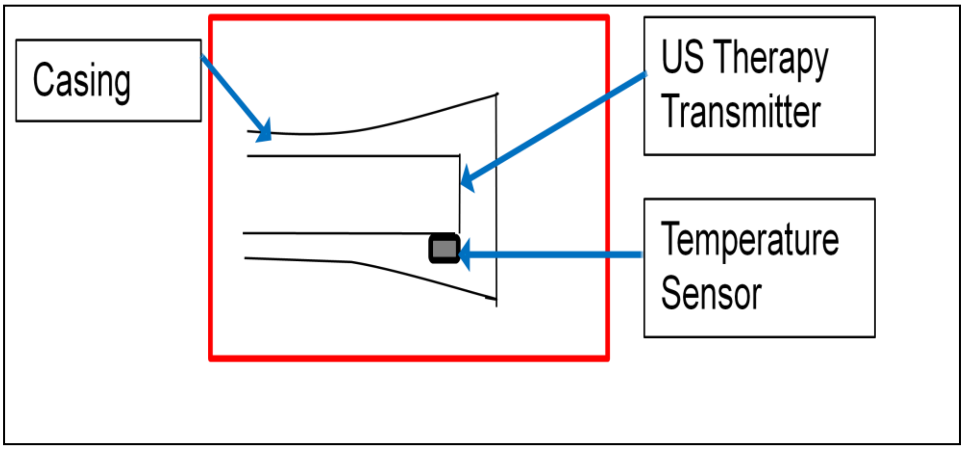


Figure 4.12 Application of temperature monitoring in ultrasound therapy

CHAPTER 5

CONCLUSION

A temperature monitoring system for ultrasound therapy machine has been developed. This system is able to cover the range from 35°C to 55°C with a resolution of 0.1°C.

This system consists of temperature sensor circuit, analog to digital converter and graphical user interface. This system is developed to be integrated with the ultrasound therapy machine as one of the important safety feature.

For the purpose of integration, FPGA may be used to as high speed system is needed for the ultrasound therapy generation and monitoring. Other than that, the ultrasound therapy is optimum to be used in water. Thus, a temperature sensor that can be immersed in water is needed to replace the semiconductor sensor. A suitable one for that purpose is the infrared temperature sensor.

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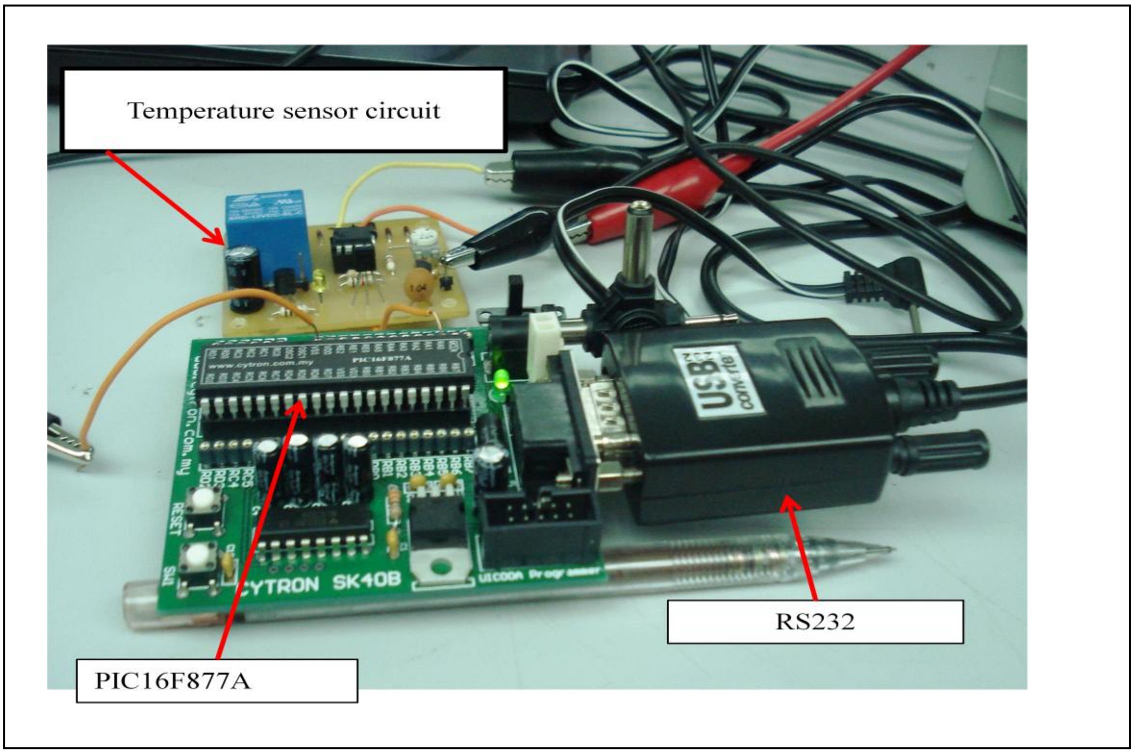
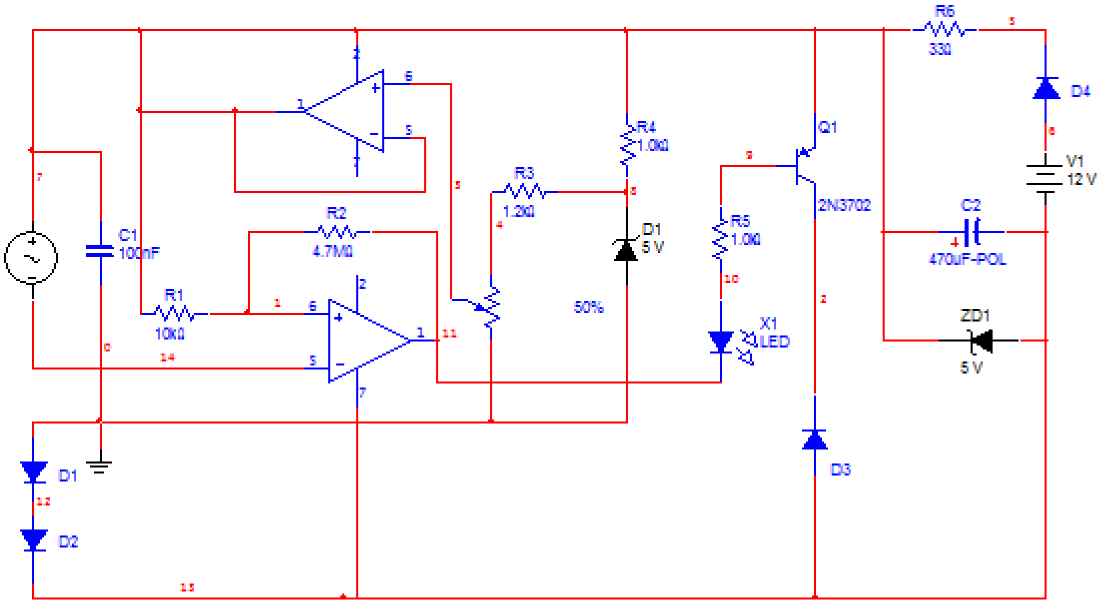
APPENDIX A

Full System of Temperature Monitoring Project for Ultrasound Therapy Machine



Schematic Diagram of Temperature Sensor Circuit



APPENDIX B

Full Source Code for ADC Programming in PIC C Compiler

```
void main()
{
float V;//T;
  setup_adc_ports(AN0);
  setup_adc(ADC_CLOCK_INTERNAL);
  setup_psp(PSP_DISABLED);
  setup_spi(SPI_SS_DISABLED);
  setup_timer_0(RTCC_INTERNAL|RTCC_DIV_1);
  setup_timer_1(T1_DISABLED);
  setup_timer_2(T2_DISABLED,0,1);
  setup_comparator(NC_NC_NC_NC);
  setup_vref(FALSE);

  // TODO: USER CODE!!
V=read_adc();
V=(V*1/51);
printf("Voltage = %6.4f\n\r",V);
T=100*V;
printf("Temperature= %3.1f\n\r degree Celcius",T);
putc(0x0D);
putc(0x0A);
}
```

Hex file

```
#include <16F877A.h>
#device adc=10

#FUSES NOWDT                 //No Watch Dog Timer
#FUSES HS                    //High speed Osc (> 4mhz)
#FUSES NOPUT                 //No Power Up Timer
#FUSES NOPROTECT             //Code not protected from reading
#FUSES NODEBUG               //No Debug mode for ICD
#FUSES NOBROWNOUT            //No brownout reset
#FUSES NOLVP                 //No low voltage prgming, B3(PIC16) or
B5(PIC18) used for I/O
#FUSES NOCPD                 //No EE protection
#FUSES WRT_50%               //Lower half of Program Memory is Write
Protected

#use delay(clock=20000000)
#use rs232(baud=9600,parity=N,xmit=PIN_C6,rcv=PIN_C7,bits=8)
```

APPENDIX C

Full Source Code of Graphical User Interface in Visual Basic 6.0

Form 1

```
'Declare Variables
    Dim StartTime As Variant
    Dim StopTime As Variant
    Dim ElapsedTime As Variant
    Dim TempF As Variant
    Dim TempC As Variant
    Dim InData As String

Private Sub cmdExit_Click()
    'Message box confirm the user whether quit or cancel quit
    answer = MsgBox("Do you want to quit?", vbExclamation + vbOKCancel
+ vbDefaultButton1, "Exit")
    If answer = vbOK Then
    'Exit the program
    End
    Else
    MsgBox "Action canceled", vbInformation, "Cancel"
    End If
End Sub

Private Sub cmdHelp_Click()
    'Go to help page when the user click on help button
    Form3.Show
    Unload Form1
End Sub

Private Sub cmdStart_Click()
    'Message box confirm the user whether startt or cancel start
    begin = MsgBox("Start a new session?", vbOKCancel + vbQuestion +
vbDefaultButton1, "Start")
    If begin = vbOK Then

    'Start a new session Establish and print starting time
    StartTime = Now
    lblStart_TimeD.Caption = Format(StartTime, "hh:mm:ss")
    lblStop_TimeD.Caption = ""
    lblElapsed_TD.Caption = ""
    End If
```

```
    'Get input from MSComm and display temperature during start
    MSComm1.InputLen = 10
    If MSComm1.InBufferCount > 10 Then
        InData = MSComm1.Input
        MSComm1.InBufferCount = 0
        lblTemp1.Caption = InData
    End If

End Sub

Private Sub cmdStop_Click()

    'Message box confirm the user whether stop or cancel stop
    nono = MsgBox("Stop this current application?", vbOKCancel +
vbDefaultButton1 + vbExclamation, "Stop")
    If nono = vbOK Then

    'Find the ending time, compute the elapsed time
    'Put both values in label boxes
    StopTime = Now
    ElapsedTime = StopTime - StartTime
    lblStop_TimeD.Caption = Format(StopTime, "hh:mm:ss")
    lblElapsed_TD.Caption = Format(ElapsedTime, "hh:mm:ss")

    'Put the stop temperature in label boxes
    MSComm1.InputLen = 10
    If MSComm1.InBufferCount > 10 Then
    InData = MSComm1.Input
    MSComm1.InBufferCount = 0
    lblTemp2.Caption = InData
    End If

End Sub

Private Sub cmdUserManual_Click()
    Form4.Show
    Unload Form1
End Sub

Private Sub Form_Load()
    MSComm1.PortOpen = True
End Sub

Private Sub Form_Unload(Cancel As Integer)
    MSComm1.PortOpen = False
End Sub

'Time and Date (Calendar) Display
Private Sub Timer1_Timer()
Dim Today As Variant
```

```
Today = Now
lblDay.Caption = Format(Today, "dddd")
lblMonth.Caption = Format(Today, "mmmm")
lblYear.Caption = Format(Today, "yyyy")
lblNumber.Caption = Format(Today, "d")
lblTime.Caption = Format(Today, "h:mm:ss ampm")
End Sub
```

Form 2

```
Private Sub cmdStartDemo_Click()
   Form4.Show
   Unload Form2
End Sub
```

Form 3

```
Private Sub cmdBack_Click()
   Form1.Show
   Unload Form3
End Sub
```

Form 4

```
Private Sub Command1_Click()
         Form1.Show
         Unload Form4
End Sub
```