DEDICATION

This project is dedicated to Almighty God, the Master of the universe for His never-ending grace over me to complete this academic programme successfully.

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CERTIFICATION

This is to certify that this project titled "Design and implementation of contactless height measuring instrument" by Adebayo Olamilekan Emmanuel meets the minimum requirements governing the award of Bachelor Degree in Electricaland Electronics Engineering of Federal University Oye-Ekiti, Nigeria.

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ABSTRACT

This report presents the design and implementation of contactless height measuring instrument. This project is based on developing and creating a device that utilizes ultrasonic sensors to determine height of an object ranging up to 200cm or 2m. The device is intended to be used as an alternative to the other more bulky and expensive models found either at home or at health centers. The ultrasonic height measurement device makes use of ultrasonic sound transducers to generate ultrasounds which is echoed back when it comes in contact with the target object. This thus eliminates the need for physical contact between the target object and the measuring device. The design includes ultrasonic sensor, composite framework, a PIC microcontroller, wiring, programmed with Micro C Pro IDE and Proteus virtual workbench is used in this design.

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Glory be to God in the highest (Amen)

CHAPTER ONE

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Height measuring instrument is an essential indicator of human health. Most people likely know their height up to a certain point. But even being half an inch to an inch shorter could be a very important indicator to your health. For children, it is important to monitor that they are growing at a healthy rate, and for the elderly it is important to monitor whether or not their height decreases. The importance of the accurate measurement of various basic and derived quantities cannot be over-emphasized as this not only forms the basis of comparison of these quantities but also shows size or amount of a particular entity. The measure of an entity can be judged by its magnitude and dimension (unit). Distance is often commonly measured using the meter rule, scale, measuring tape etc. and these devices often requires a physical contact with the target whose distance or height is to be measured.

The measurement of height which denotes the vertical distance of an object from a horizontal platform is often carried out in hospitals, sport centres and fashion houses. It could be measured in centimeter (metric system) and feet and inches (imperial system). The measurement of the height of humans is especially useful for various analysis such as the calculation of the Body Mass index (BMI); a measure of the body fat based on the weight and the height, the clothing size of an individual etc. The height of an individual also serves as criteria for recruitment into the military and certain sports and games.

The measurement of distance often depends on three important factors .i.e. medium, source and target. The source is a point from where distance is to be measured and target is the object whose distance is to be measured. The medium lies between source and target. The ultrasonic height measurement device makes use of ultrasonic sound transducers to generate ultrasounds which is echoed back when it comes in contact with the target object. This thus eliminates the need for physical contact between the target

1.2 STATEMENT OF THE PROBLEM

The measurement of height of an object is commonly done with measuring devices such as measuring tape, meter rule etc. These devices lacks the convenience of use and often required a physical contact between the source and the target objects, hence the need for an inexpensive contactless height measurement device is constructed and implemented ranging up to 200cm or 2m.

1.3 MOTIVATION

The need for the design of contactless height measuring instrument is to contribute to the improvement in measurement. The outbreak of Ebola disease with its peculiar mode of transmission and the post-ebola era precautions motivated this project which enables the measurement of patient's height without touching them.

1.4 SIGNIFICANCE OF THE STUDY

This contactless height measuring instrument allows the user to measure the height of the object introduced when positioned accurately without contact unlike meter rule, tape rule which requires physical contact with the object that needs to be measured. Height is one of the important indicators of human health. Most people likely know their height up to a certain point. But even being half an inch to an inch shorter could be a very important indicator to your health. For children, it is important to monitor that they are growing at a healthy rate, and for the elderly it is important to monitor whether or not their height decreases

1.5 PROJECT AIM AND OBJECTIVES

AIM

The aim of this work is to design and construct an ultrasonic height measurement device.

OBJECTIVES OF THE STUDY

The specific objectives of the design are to:

- Design an ultrasonic electronic device capable of calculating distance using reflected signal.
- Construct a mechanical frame work 250cm long.
- Evaluate the performance of the developed device.

1.6 SCOPE OF THE PROJECT

This project presents the functionality of an ultrasonic height measuring device. It measures a patient's height without contact.
Although there are a few limitations of this design they include:

- Any object introduced that is below 100cm and above 200cm, an out of range error would be displayed
- Due to the relative absorptivity and uneven nature of the human hair, the use of thin sheet of paper with negligible thickness over the head should be positioned well in order to get accurate readings.

CHAPTER TWO

THEORITICAL BACKGROUND

2.1 LITERATURE REVIEW

Ultrasound sensors are very versatile in distance measurement. They are always providing the cheapest solutions. Ultrasound waves are useful for both the air and under water (J. David and N. Cheeke, 2002). Ultrasonic sensors are quite fast for most of the common applications. In simpler system a low cost version 8 Bit microcontroller can also be used in the system to lower the cost. This system has been developed and tested for use in a robotic sewer inspection system under development. Sewer network is prevalent everywhere. Sewer lines may be made of circular pipes for smaller sizes or a covered masonry channel for larger sizes. Smooth working of sewer system is a present day necessity for keeping the cities clean. Generally maximum portion of sewer pipelines are underground and sewer blockages have become quite common. The blockages have become more frequent due to the dumping of polythene bags, hair and solid materials into the sewer system (S. P. Singh, A. Verma, and A. K. Shrivastava, Jul 2008 Vol No 2 pg 73-81).H. He, et al. had designed distance measurement device using S3C2410. The temperature compensation module had also been used to improve the precision (H. He, and J. Liu, Oct 2008). Y. Jang, et al, had studied portable walking distance measurement system having 90% accuracy (Y. Jang, S. Shin, J. W. Lee, and S. Kim, Aug 2007). C. C. Chang, et al. had studied the ultrasonic measurement system for underwater vehicles (C. C. Chang , C. Y. Chang and Y. T. Cheng, April, 2004). Ultrasonic sensors have variety application as distance measurement, obstacle avoiding and anti-collision detection, robot navigation, measurement in automotive parking assistance systems, measurement of air flow velocity - anemometer, medical ultrasonography, non-destructive testing, piezoelectric transducers, level must be taken to avoid these. For the transmitted wave to echo back to the receiver, the target surface must be perpendicular to the transmitter. Round objects are therefore most easily sensed since they always show some perpendicular face. When targeting a flat object, care must be taken to ensure that its angle with respect to the sensor does not exceed a particular range.

Ultrasonic sensors typically have a "dead zone" immediately in front of them in which objects cannot be detected because they deflect the wave back before the receiver is operational. (This is because reverberations from the transmitter force the receiver to pause a moment before beginning to listen for the echo). Some materials are more absorbent than others, and these will reflect less ultrasound. This complicates using the attenuation method to measure the distance of arbitrary objects [7-29].

Lasers are now commonly used in the medical field for measurement including facial imaging, corneal thickness, and limb length. In these applications, lasers are easy to operate and possess high measurement reliability (Kusnoto B 2002). Although, lasers are not used in the medical field to measure height, veterinarians use laser devices to measure animal height. In comparison to a conventional measuring stick, a laser device for measuring height at the withers of horses and ponies was demonstrated to be reliable and accurate. The term SONAR refers to Sound Navigation and Ranging. Ultrasound scanners can be regarded as a form of 'medical' Sonar. As early as 1826, Jean-Daniel Colladon, a Swiss physicist, had successfully used an underwater bell to determine the speed of sound in the waters of Lake Geneva. In the later part of the 1800s, physicists were working towards defining the fundamental physics of sound vibrations (waves), transmission, propagation and refraction. One of them was LordRayleigh in England whose famous treatise "the Theory of Sound" published in 1877 first described sound wave as a mathematical equation, forming the basis of future practical work in acoustics. As for high frequency 'ultrasound', Lazzaro Spallanzani, an Italian biologist, could be credited forit's discovery when he demonstrated in 1794 the ability of bats navigating accurately in the dark was through echo reflection from high frequency inaudible sound.

Very high frequency sound waves above the limit of human hearing were generated

This current work is based on the same principle with some little modifications in which the project utilizes HC-SR04 ultrasonic sensor, Capacitors, Crystal oscillator, programmed with Mikro C Pro IDE, PIC microcontroller unit (PIC16F628A), a LCD display screen to display the height of an object and other passive components. Although there exist different types of stadiometer, they are mostly un-automated, stressful and prone to errors. The contactless stadiometer thus provides a modern approach towards measurement of an individual height without physical contact.

CHAPTER THREE

3.1 DESIGN METHODOLOGY

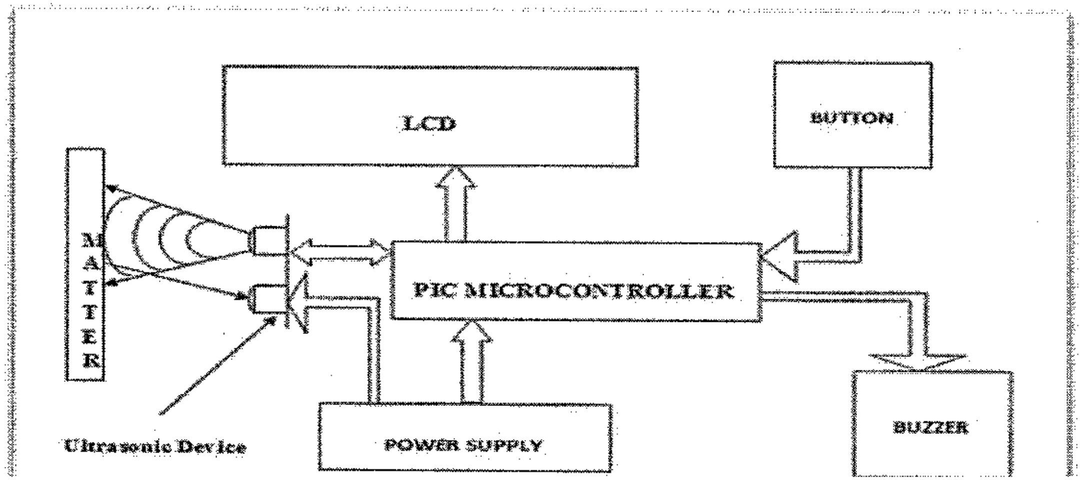
The methodology in this project involves the software implementation and the Hardware implementation.

The software implementation includes:

i. Definition of task
ii. Designing the system
iii. Writing the control program using Mikro C PRO IDE
iv. Testing and debugging the program in Proteus Virtual Workbench

The Hardware implementation includes;

i. Designing of the rectangular hollow mild steel bars
ii. Designing of the head section, base section and main body
iii. Coupling of the whole design



3.2 REQUIREMENTS SPECIFICATIONS

The contactless height measuring instrument is a low-cost, non-contact and easy-to-install measurement device. This design is highly-accurate ranging up to 200cm or 2m with power input of 9VDC which is easily replaceable when it is faulty.

3.3 DESIGN

3.3.1 INTRODUCTION

The contactless height measurement device (stadiometer) basically measures the height of the user via an ultrasonic sensor module at a fixed height on the frame of the device. By measuring the distance of the user from the sensor module and subtracting the result from the reference height, the height of the user can be easily calculated.

The contactless stadiometer provides the advantage of being easily operated by a single user during usage. The design of the contactless stadiometer had the following key factors in consideration. These amongst others include:

- Mobility and Portablility: Light weight and easily movable
- Inexpensive: Use relatively cheap and readily available components
- Maintenance : The device should be relatively maintenance free
- Ease of Operation: Device should require little or no technical know-how to operate.

3.3.2 THE PIC MICROCONTROLLER (PIC16F628A)

The Micro-controller is a chip that combines the microprocessor with one or more other components. These components contains memory, ADC (Analog-to-Digital Converter), DAC (Digital-to-Analog Converter), parallel I/O interface, serial I/O interface, timers and counters.PIC is a family of modified Harvard architecture microcontrollers made by Microchip commonly used in educational programming as they often come with the easy to use PIC legislator' software.

The PIC microcontroller is built for the purpose of dealing with specific tasks, such as displaying information in a microwave LED or receiving information from a television's remote control and is mainly used in products that require a degree of control to be exerted by the user.

The microprocessor responses to arithmetically operate the binary data which likes a Central Processing Unit (CPU) in a computer. However, its speed, general purpose registers, memory addressing and instruction set are very low compare with a CPU. Therefore, it can be illustrated as a low level CPU. The memory is used for storing the data, programming instruction and results. It also provides this information to other units. So that the microcontroller can be processed by pre-write instruction without computer or any other devices. The ADC and DAC can do convert signal between analog signal and digital. The analog signal usually is a voltage number in a range. Such as a temperature sensor, it can convert the temperature value to a specific voltage value. Then, this voltage value can be converted to digital value as binary via ADC. In addition, the parallel I/O interface and serial I/O interface supply one or more ports for connecting sensors on the microcontroller. The timers and counters of microcontroller provide a specific frequency. In this study, the PIC16F628A micro-controller has been chosen to control sensors for building an automatic control system, which includes all components.

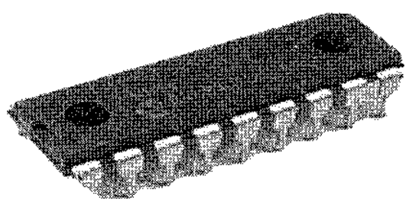


Fig 3.2: The PIC16f628A Microcontroller [31]

required. One method is to control it by a quartz crystal; this is cut so that it vibrates mechanically at the design frequency, and is coupled to the electronics by the piezoelectric effect. A 12 MHz crystal oscillator is an electronic circuit, whose output frequency is controlled by a quartz crystal to repeat 12 million times per second and 4MHz was used in the design of this project.

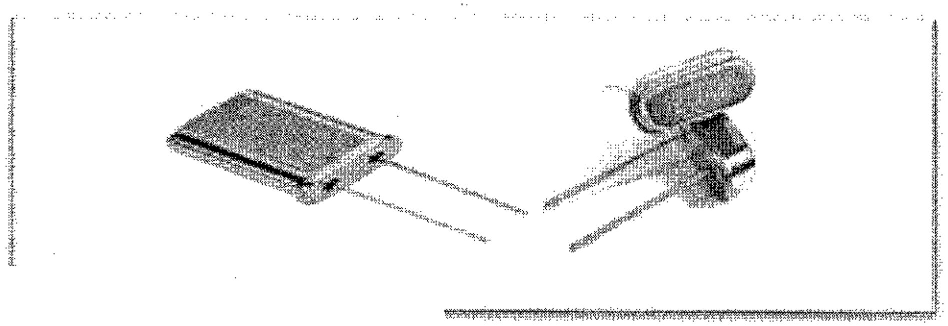


Fig 3.3: Crystal Oscillators [32]

3.3.4 THE LIQUID CRYSTAL DISPLAY (LCD)

A liquid-crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly.

LCDs are used in a wide range of applications including computer monitors, televisions, instrument panels, aircraft cockpit displays, and signage. They are common in consumer devices such as DVD players, gaming devices, clocks, watches, calculators, and telephones, and have replaced cathode ray tube (CRT) displays in most applications. They are available in a wider range of screen sizes than CRT and plasma displays, and since they do not use phosphors, they do not suffer image burn-in. LCDs are, however, susceptible to image persistence. The LCD used is 16 by 2 alphanumeric

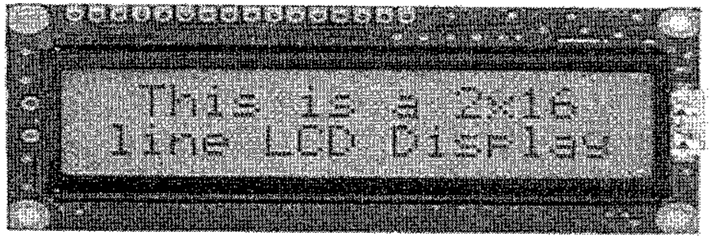


Fig 3.4: LCD Display [33]

3.3.5 HC-SR04 ULTRASONIC TRANSDUCER

Ultrasonic is the application of ultrasound. The ultrasound is a vibration of frequency which is greater than the upper limit of human hearing range. Generally ultrasound has frequency ranging from 20 kHz to several GHz. Ultrasonic sensors (also known as transceivers when they both send and receive) work on a principle similar to radar or sonar which evaluate attributes of a target by interpreting the echoes from radio or sound waves respectively. Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor. These sensors calculate the time interval between sending the signal and receiving the echo to determine the distance to an object. This technology can be used for measuring: wind speed and direction (anemometer), fullness of a tank and speed through air or water. For measuring speed or direction a device uses multiple detectors and calculates the speed from the relative distances to particulates in the air or water. To measure the amount of liquid in a tank, the sensor measures the distance to the surface of the fluid. Further applications include: humidifiers, sonar, ultrasonography, Burglar and testing. These systems typically use a transducer which generates sound waves in the ultrasonic range, above 18,000 hertz, by turning electrical energy into sound, then upon receiving the echo turn the sound waves into electrical energy which can be measured and displayed. The technology is limited by the shapes of surfaces and the density or consistency of the material. For example foam on the surface of a fluid in a tank could distort a reading.

Ultrasound has its application in many fields. It is used in medicine for

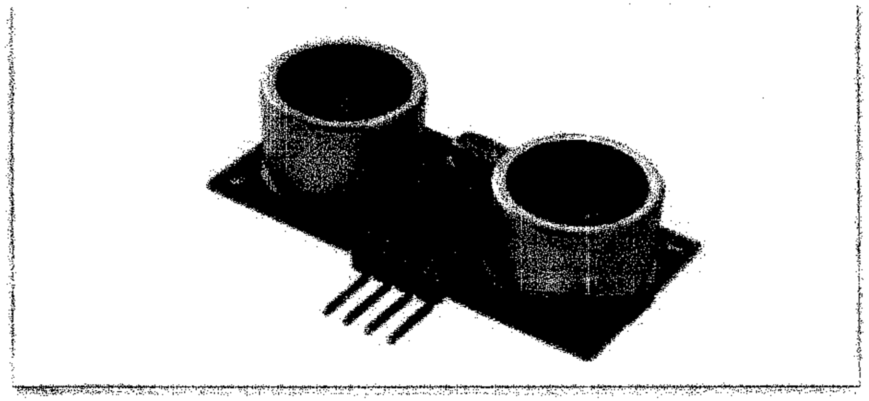
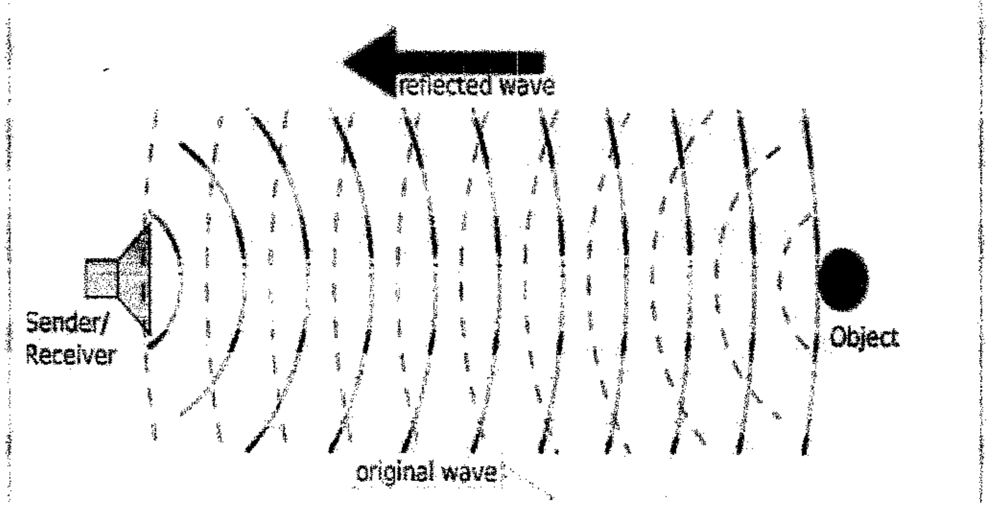


Fig 3.5: The ultrasonic sensor module [34]

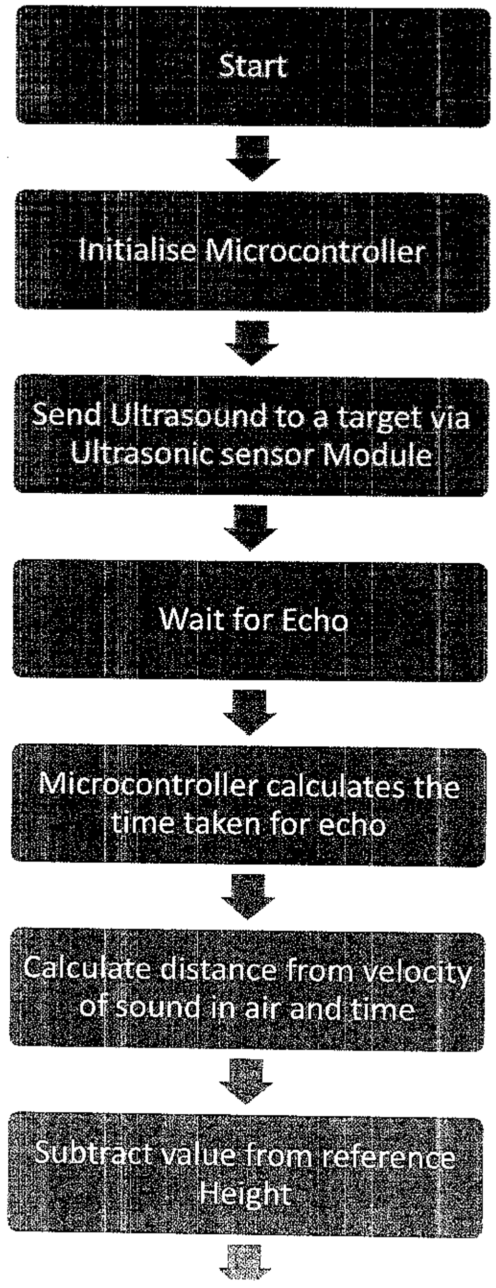
3.3.6 MODE OF OPERATION

The device basically works by sending short burst of ultrasonic sound waves against a target object and measuring the time taken for the echo to return. Using the speed of sound in air and the time taken for echo to return, the distance measured is then calculated with the appropriate formula.



The operation usually occurs in two stages as stated below:

- The Contactless Measurement of the user's height: This is achieved through the use of an ultrasonic sensor module which sends ultrasonic sound waves and waits for an echo to be received when the waves comes in contact with an object.
- Interpretation and Display of Measured Height: The data received from the ultrasonic sensor module is then fed into the PIC microcontroller which is programmed to do the analysis and calculations of converting the time taken for an echo to be received to its equivalent distance. The result of the analysis is afterward displayed on a LCD screen as illustrated in the flow chart shown in Fig 3.7


Start
Initialise Microcontroller
Send Ultrasound to a target via Ultrasonic sensor Module
Wait for Echo
Microcontroller calculates the time taken for echo
Calculate distance from velocity of sound in air and time
Subtract value from reference Height

3.3.7 DESIGN ANALYSIS

The contactless distance measurement device is based on the measurement of distance with the use of an ultrasonic sensor device controlled by a microcontroller. The microcontroller being the heart of the device triggers the ultrasonic sensor device. Once the trigger is received by the ultrasonic sensor device, the sensor emits ultrasound wave in a linear direction towards the obstacle and awaits the reception of echo which is being reflected by the obstacle. Upon reception of the echo the time 'Tt' between pulse emission and echo reception is being derived by the microcontroller in the Timer0 module. The derived time 'Tt' is further divided by two (2), because the time needed for the transmitter and receiver to detect the obstacle or object introduced. Dividing the 'Tt' by two yields time 'T'. The derived time T is then multiplied by the speed of sound in air (340 m/s) to calculate the distance'd' from the ultrasonic device to the obstacle (the plank on top of the head) which is then displayed on the LCD screen.

Mathematically:

Distance = Speed * Time

Distance = S * T

Where

T = Time of travel of the ultrasound in one direction

$$T = \frac{Tt}{2}$$

Tt = Time taken for to and fro movement of ultrasonic sound waves

S = Speed of Sound in air (340m/s)

$$\text{Distance} = \frac{S * Tt}{2}$$

allow 10 cycles of 40 kHz sine wave. The sine wave varying between 0-1V passes through the switch to the gain Amplifier. The level shifter and gain amplifier gives a sine wave with output varying between -10V and +10V and the transmitter sends out a burst of 10 pulses. As the transducers are directional they are positioned to face the target. The microcontroller waits to receive the pulses for a maximum duration of 12 milliseconds. This is the time taken for the ultrasound waves to travel a maximum distance of 4meters

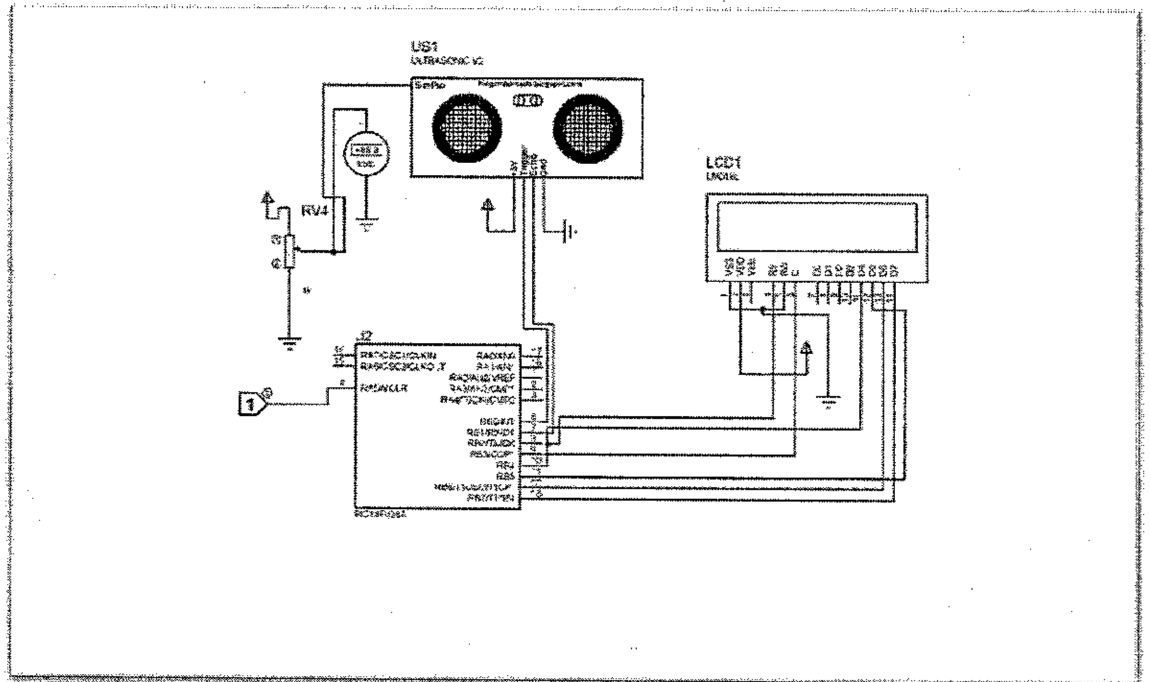


Fig 3.8: Circuit Diagram of the contactless height measuring instrument

The time of flight gives twice the time taken to traverse a unit distance and if it doesn't receive the pulses within this time it is considered as absence of object or object out of range. Once the pulses are received the microcontroller counts 10 pulses with a time spacing of 25 microseconds only then the measurement is considered valid and the computation using the formula is implemented. Necessary hex to decimal conversion and decimal to ASCII conversions are performed and displayed on the LCD. The basic steps taken in the programming are outlined below

- Provide TRIGGER to ultrasonic module
- Listen for Echo
- Start Timer when ECHO HIGH is received
- Stop Timer when ECHO goes LOW
- Read Timer Value
- Convert it to Distance
- Subtract value from reference height
- Display it on the LCD

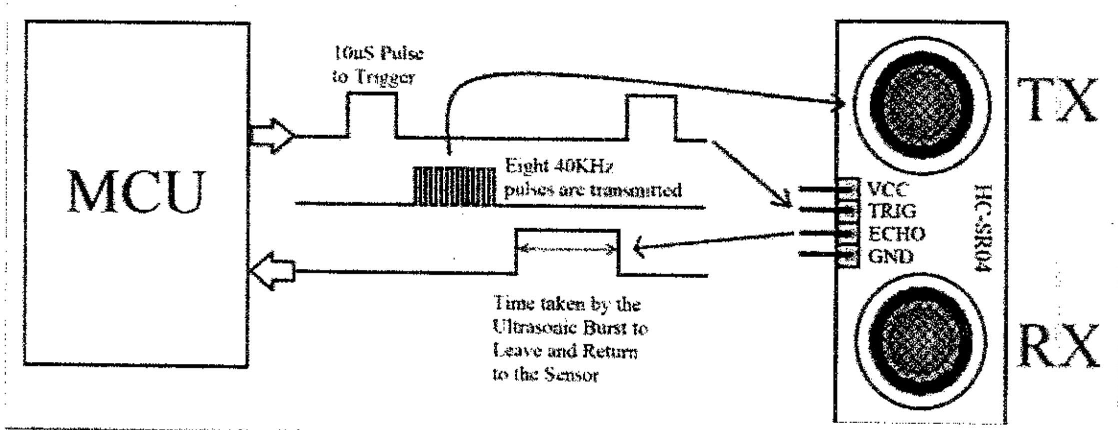


Fig 3.9: Operation of the ultrasonic module [37]

T1CON: TIMER1 CONTROL REGISTER (ADDRESS 10h)

	bit 7							bit 0
	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
	—	—	T1CKPS1	T1CKPS0	T1OSCEN	$\overline{\text{T1SYNC}}$	TMR1CS	TMR1ON

Fig 4.0: The Timer1 Register [38]

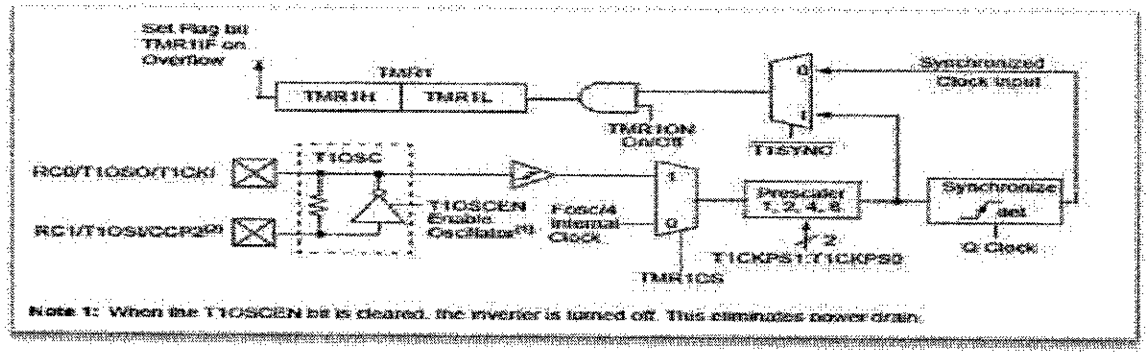


Fig 4.1: The Timer1 flags [39]

Since module is used as a Timer, it should use internal clock (Fosc/4), i.e TMR1CS = 0. Prescaler is used to divide the internal clock (Fosc/4) and the prescaler is set to 2, i.e. T1CKPS1 = 0 and T1CKPS0 = 1. T1SYNC bit is ignored when TMR1CS = 0. Since the internal clock (Fosc/4) is used the oscillator can be disabled i.e. T1OSEN = 0. TMR1ON bit can be used to ON or OFF timer as required.

Timer 1 is initialized as a timer: T1CON = 0x10

To TURN ON the Timer: T1CON.F0 = 1 or TMR1ON = 1

To TURN OFF the Timer: T1CON.F0 = 0 or TMR1ON = 0

Fosc is the oscillator frequency, and an 8MHz crystal is used

The MCU is programmed with Mikro C PRO IDE and the hex files are burnt into the PIC with the PIC Kit IDE.

3.4 CONSTRUCTION PROCEDURE

The construction of the device is done in two main stages:

- The construction of the mechanical framework
- The construction of the electrical panel

3.4.1 THE MECHANICAL FRAMEWORK

Rectangular hollow mild steel bars were chosen for the mechanical framework due to its height strength and relative light weight. The device which measures 2000mm * 500mm was constructed in the semblance of the letter "H". It consist of three sections: the Head section, the main body and the base

Main Body

- The stock material was marked out and cut to desired sizes using a suitable hack saw.
- Holes ranging from 10mm to 12mm were then drilled at desired positions to accommodate screws for attaching the base boards and the head unit.
- The device was also designed to be easily dismountable hence; the whole unit was divided into two equal halves.
- The cut parts were then welded and respective halves screwed to make a single unit

The Head and Base Sections

- `Ply-boards were marked out, cut, drilled and screwed to the already prepared rectangle base of the main body.

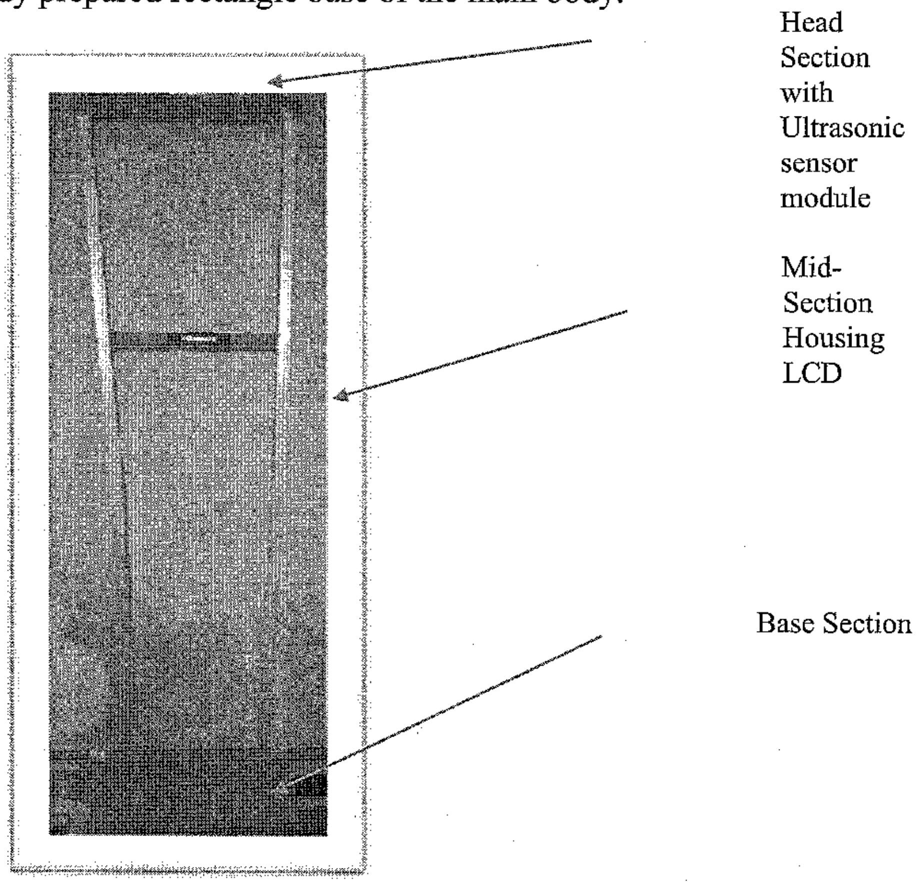


Fig 4.2: Main Parts of the Contactless height measuring instrument

3.4.2 ELECTRONIC BOARD AND PANEL

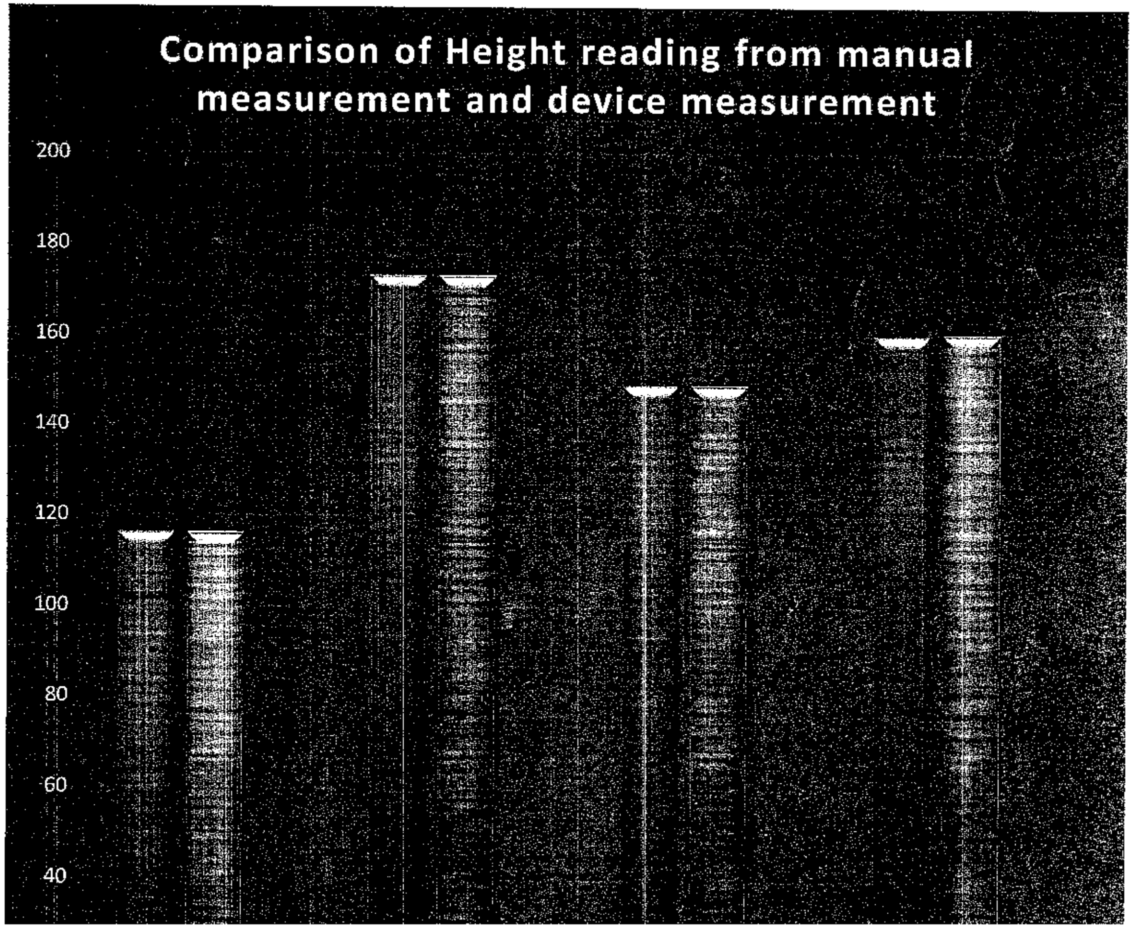
Calculating the percentage error of the device's reading is given below:

$$Percentage\ error = \frac{error}{actual\ measurement} * 100$$

$$\%\ error = \frac{180.1 - 180}{180} * 100$$

$$Therefore, \%\ error = 5.5\%$$

From the percentage error calculated, it can be seen that the device reading is relatively error free.



It can be seen from above graph that the height reading from a manual measurement and device measurement clearly show no variations in the height readings.

The second phase of the analysis entails testing the performance of the device on the heights of objects within and outside its calibrated range.

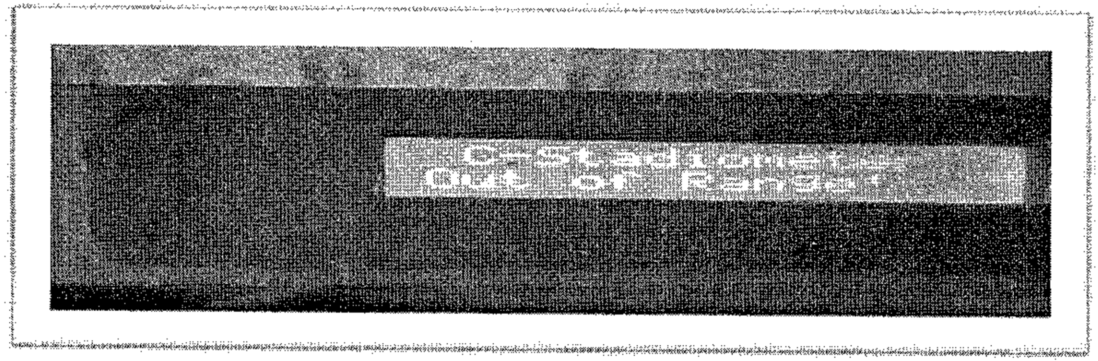
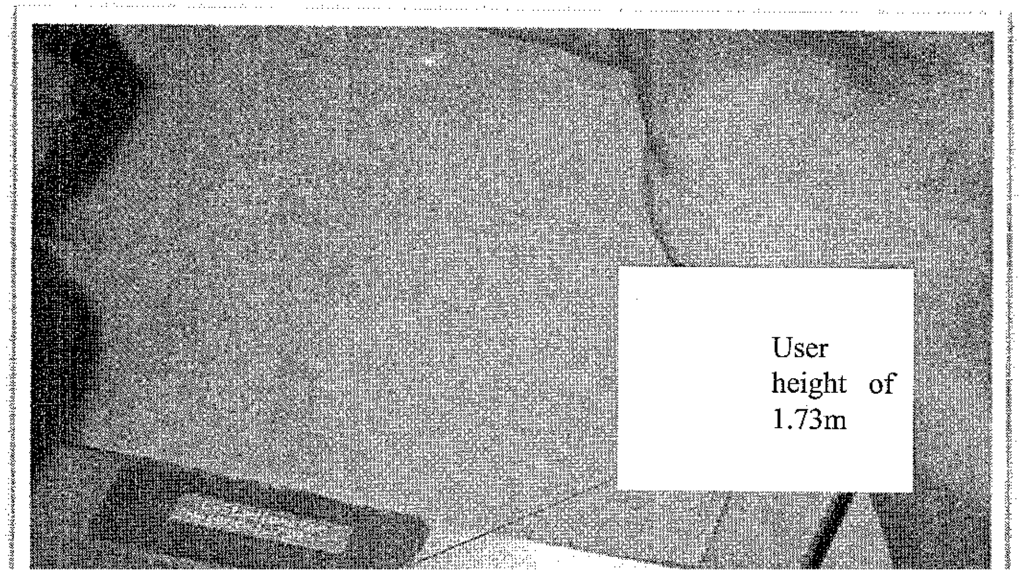


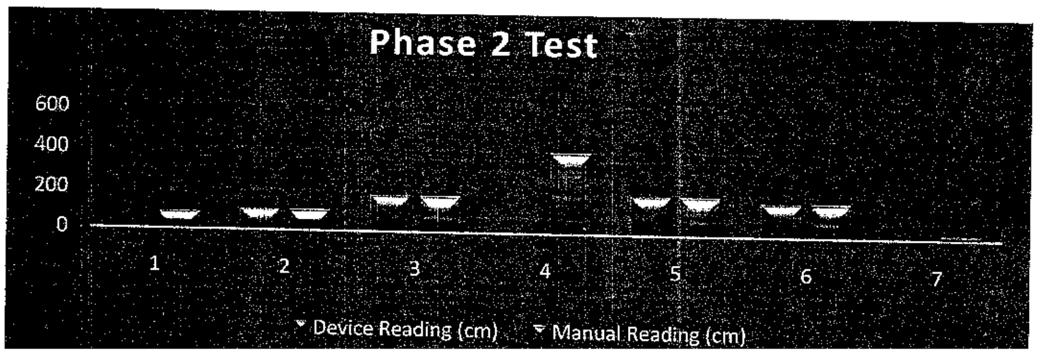
Fig 4.7 Analysis phase 2 device displaying "Out of range" for a height of 1m



The values obtained in Fig 4.9 were the manual and device measurement

S/N	Device Reading (cm)	Manual Reading (cm)
1	Out of Range	80
2	100	100.1
3	173	173
4	Out of Range	400
5	189	189
6	164	164.2
7	Out of range	20

Fig 4.9: Device and manual measurement readings



4.3 DISCUSSION OF RESULTS OBTAINED

The above results clearly show little variations in height readings as measured using a measuring tape and that obtained from the device. Also, an "OUT OF RANGE" notification is displayed by the LCD for measurement outside the calibrated range of the device 100cm to 200cm (1m - 2m).
This indicates the device is not only functional but also quite efficient and thus fulfills the objectives of this work.

4.4 PROJECT MANAGEMENT

The device is basically maintenance free with major maintenance having occasionally changing of the battery. To change the battery the following steps should be taken:

- Unscrew the two holding screw at the back end of the device
- Carefully slide the out the old
- Replace the battery with a new one, screw back the cover and power on to use.

4.5 PRECAUTIONS

The following precautions should be taken to ensure accurate result

- Readings should be taken only after the user is properly positioned under the ultrasonic sensor and the reading is steady.
- Since the device is built basically on principle of reflection of sound waves, the relative sensitivity of the ultrasonic sensor module depends on the target material. It is strongest for hard surfaces such as walls, a board etc and fluctuates slightly on the human skin, and fabrics etc, thus a sheet of paper or any hard material of negligible thickness should be placed over the head to get a more stable reading