DEVELOPEMNT OFULTRASONIC LIQUID LEVEL MEASUREMENT

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
In Partial Fulfilment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved:

____

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Elidio Pedro Nhabetse

ABSTRACT

Ultrasonic system for level and distance measurement is a way of measurement that is not only efficient but is also cost effective, which make it easy to be employed in number on different situations and configurations whenever is seen fit. Day after day we are faced with a problem of making an accurate measure of the distance of objects that are located in remote places and where access to those places is inconvenient to use traditional ways of measurement. For all over the years, it has always been in the interest of engineers to be able to use sophisticated systems t be able to do measurement. One of the methods that this paper describes is the Time of Flight Method (TOF). It is based on the reflection of sound waves, which makes the wave propagation the base of the project. The technique is pulse-echo method, where wave is emitted from the ultrasonic transmitter and its corresponding echo received for further analysis by ultrasonic receiver.

Water is a very good reflector of ultrasonic waves, and therefore the project this report describes is merely a system that transmits and receives the echo reflected at the surface of the water if liquid measurement is being performed. In the case of distance measurement, is also used the same principle, so long the it is know what is being targeted by the system in hand. A microprocessor is used in this project which takes on the tasks of triggering the transmitter and calculating the distance by analysing the returned echo.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

2.1 Background of Study

Day after day we are faced with a problem of making accurate measure of the distance of objects that are located in remote places and where access to those places is inconvenient. For all over the years, many methods have been used to calculate or simply measure the distance from one point to another, or the level of liquid. Time of flight method that is used through ultrasonic transducer is a new way researcher and engineers have come out with to solve the issue of distance measurement.

The project is based upon the reflection of sound waves. Wave propagation serves as basics for this design project.

The technique that will be employed to measure the distance to the object in cause will be Pulse-echo method, where a wave is emitted from the ultrasonic transmitter and its corresponding echo received for further analysis by ultrasonic receiver. When it has to be used for liquid level measurement, a reflector will not be needed at the surface of the liquid inside a determined container, because liquid is also a good reflector of ultrasonic waves. For analysis of the reflected waves (echo), a microprocessor will be used to both generate the sound waves and also to analyse the returning (reflected) sound waves from the test object by the means of coding.

1.2 Problem Statement

With the advance of technology in this modern world, comes the need to find sophisticated ways to perform distance measurement from a predefined point to the test object. To be more precise to the subject of the project, to know the level of liquid has always been crucial mainly in chemical plants. Therefore, the need to create or design an ultrasonic transducer that can help in measuring liquid levels in tanks is of the most importance. Current level measurement techniques that are employed, either do not guarantee level of accuracy that is needed or the system itself have limitations on what have to do with the object to be examined. Cost is also another issue that concern most of the current liquid level measurements that are employed in the industries and many other places where a constant monitoring of a level of a specific tank or tanks is needed.

1.3 Significance of Project

Industries nowadays are looking for new ways to perform measurement of liquid in tanks. Ultrasonic level measurement is a reliable way to do it as not only the design of the transducer is affordable but also reliable as it gives accurate measure of the liquid in the tank.

Therefore, this design will be of great important not only to industries, but also to personal use, as it can be used not only for level measurement, but also for distance measurement.

1.4 Objectives

The objective of this project is to design an inexpensive ultrasonic transducer system that will be used both for distance measurement and also for liquid level measurement.

The system to be designed will be employed with a microprocessor that will constantly provide electrical signal to the transducer that in turn will convert it to acoustic energy (sound waves) to be sent to the test subject (either object for distance measurement or liquid surface for level measurement). The reflected sound waves will be captured by the transducer receiver that will convert the acoustic energy to electrical energy through piezoelectric effect to be analyzed by the microprocessor.

CHAPTER 2

LITERATURE REVIEW

2.1 Principle of Ultrasound

Ultrasound utilizes ultrasonic sound waves from the transducer using the piezoelectric effect. The transducer is the device that both produces and receives the sound waves through the piezoelectric effect.

Ultrasound uses sound waves of frequency above the human hearing capacity, which is above 20 kHz.

The table below depicts the different sound frequencies by type:

Less than 20 Hz	Infrasound
20 Hz to 20 kHz	Audible sound
Above 20 kHz	Ultrasound

Table 2.1: Classification of sound according to frequency

From the table above, it can be seen that the frequency where ultrasound operate are above those of human hearing capabilities.

Sound wave propagation forms the basis for the subject of ultrasonic, so the next section is reserved for it.

2.2 Sound waves

Liquids, gases and solid have the property to exhibits mechanical vibrations which travel as a wave. Those vibrations cause the sound to be propagated [1].

There are four ways of sound propagation:

- Longitudinal waves
- transverse waves

- surface waves
- Plate waves.

For ultrasound, longitudinal waves and transverse waves are of the importance of the study of level and distance measurement.

Longitudinal waves are those where the movement of each and every particle of the medium is in a direction that is parallel to that of the energy transport [1].

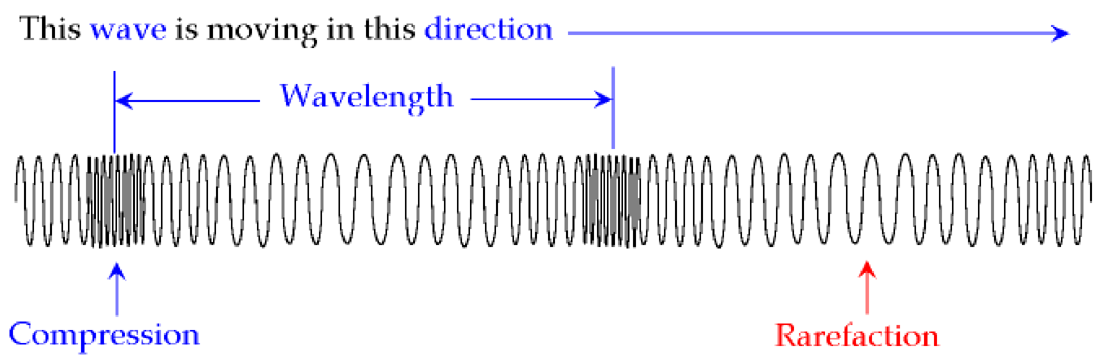


Figure 2.2(a): Longitudinal wave

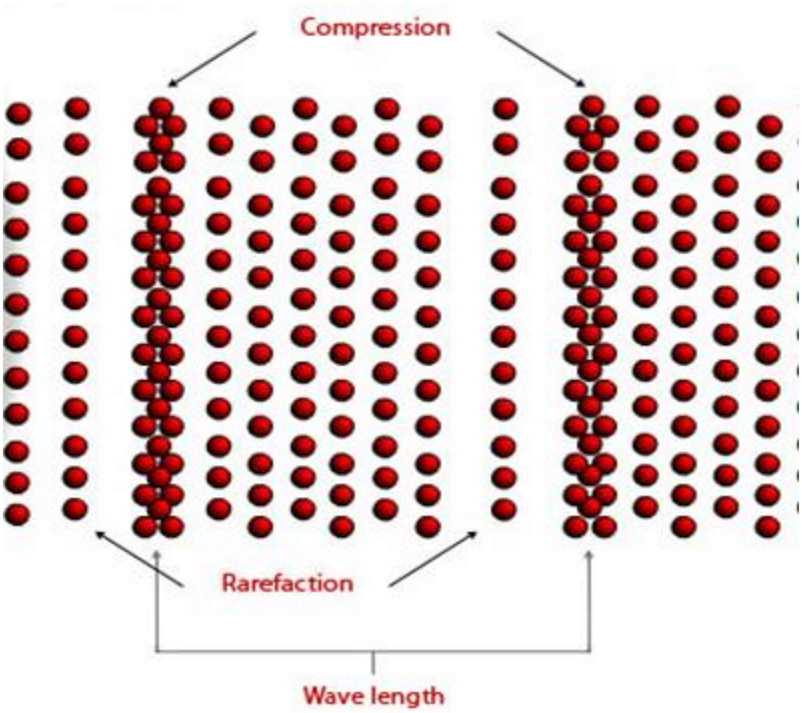


Figure 2.2(b): Molecule Representation of Longitudinal waves

In the graphs depicted above, we can see that compression is the region where molecules have greater density which makes the distance between individual molecules very small. In the other hand, rarefaction is the region where particles are further apart, since they have less density [2]. A wavelength is the distance that separates any two consecutive compressions.

If we know the speed of the medium and the frequency at which the wave is propagated, we can calculate the wavelength using the formula below:

$$\boldsymbol{\lambda = \frac{c}{f}}$$

Where:

- λ : wave wavelength
- c: speed of sound in a particular medium (340m/s in Air at room temperature)
- f: frequency of the wavelength

Unlike Longitudinal waves that are propagated in gases and liquids, Transverse waves require solid materials to be able to propagate. Here, the particles have the tendency to oscillate in the transverse direction to that of the propagation. Transverse waves are not as strong as longitudinal waves [1].

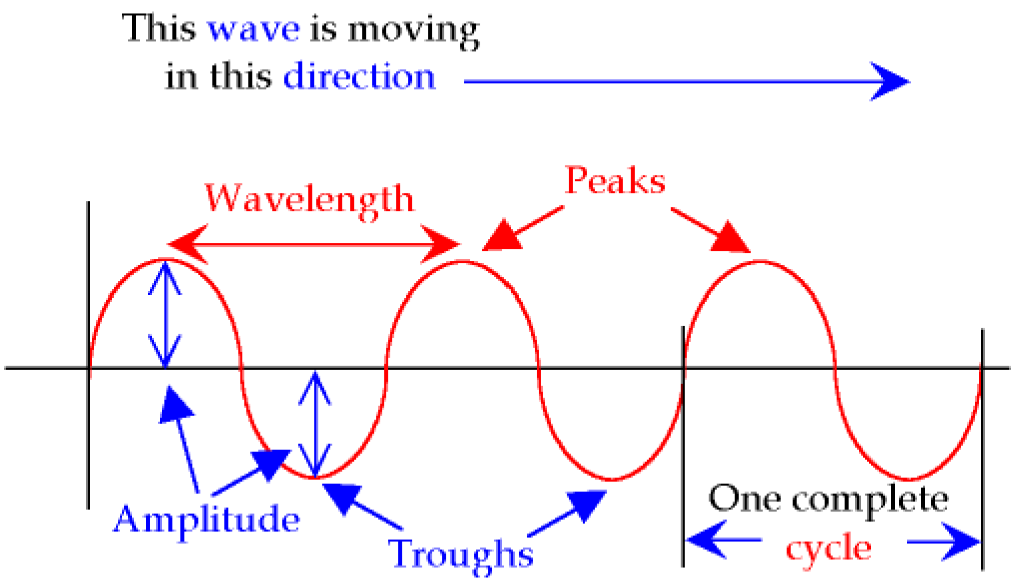


Figure 2.2(c): Transverse wave

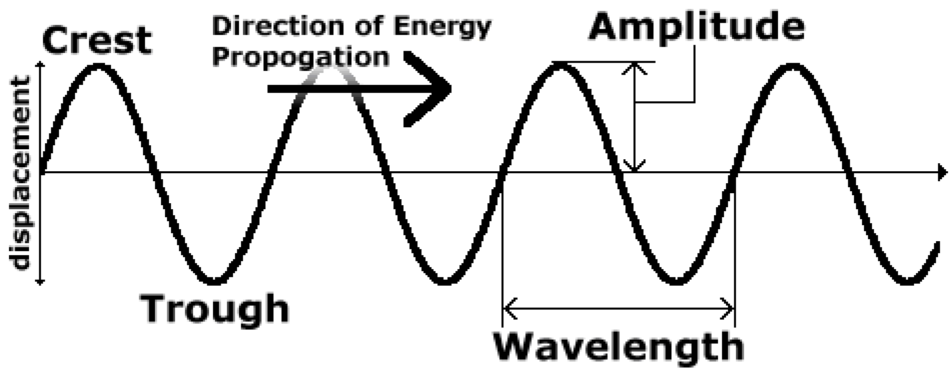


Figure 2.2(d): Transverse wave with crest and trough depicted

The wavelength of a transverse wave is the distance between two consecutive troughs.

Surface reflection can be of two forms: specular or diffuse. It all comes to depend on the size of irregularities that the reflecting surface may present. When the irregularities of the reflecting surface with respect to the wavelength are small, the surface is considered smooth, therefore the reflection being specular or as it may also be called, mirrorlike. If the irregularities are rather large with respect to the wavelength, then the surface will be considered rough, which in turn the reflected wave being diffuse, is scattered in all directions. [3]

Within the scope of liquid, ultrasound may be scattered due to the presence of small water waves if the liquid is not in rest.

Piezoelectric effect is another topic that needs to be taken into consideration when dealing with Ultrasonic.

2.3 Piezoelectric Effect

Sound is caused by vibration of particles be it in solids, gases or liquids. How those vibrations are accomplished is through the piezoelectric effect. The basis of ultrasonic is the conversion of electrical energy into mechanical vibration and the conversion of returning vibrations into electrical energy.

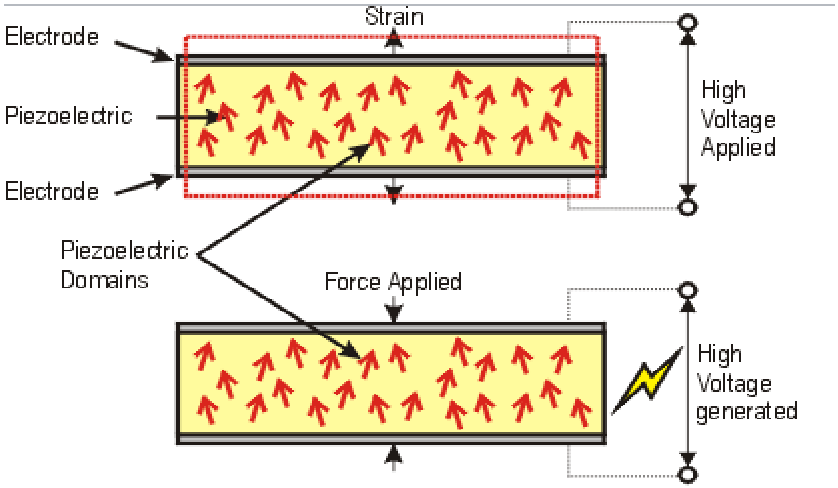


Figure 2.3(a): piezoelectric effect

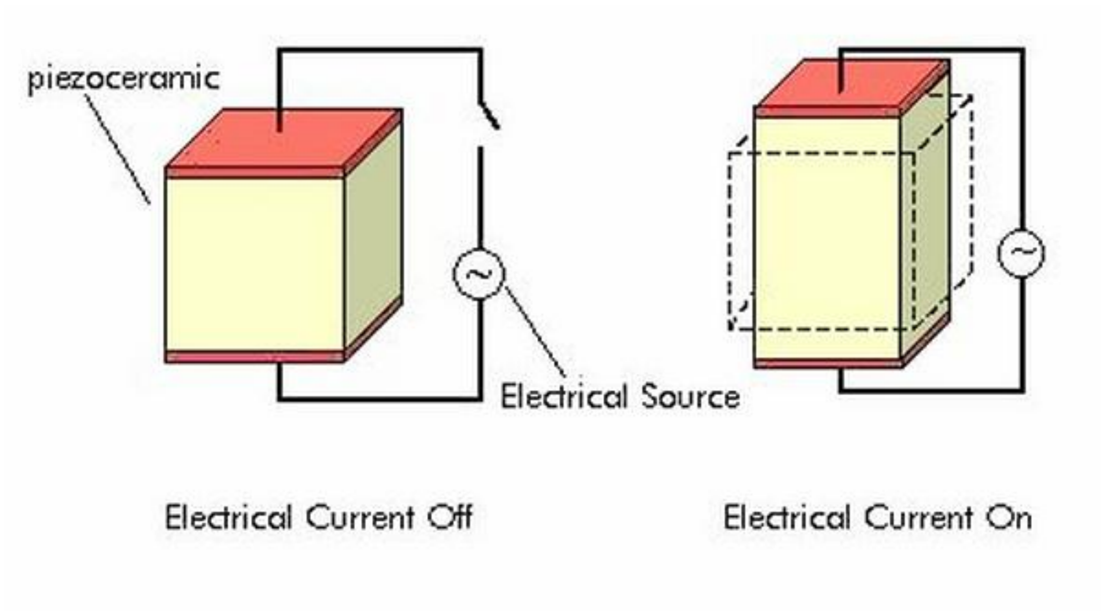


Figure 2.3(b): Vibrations due to piezoelectric effect

2.4 Pulse-echo Technique

The pulse-echo is one of the configuration methods that are used by transducers. In Pulse-echo method, a sound wave is transmitted to the surface of the object or liquid surface to be examined, and the corresponding echo is detected by the transducer after some elapsed time. Figure below depicts the above situation.

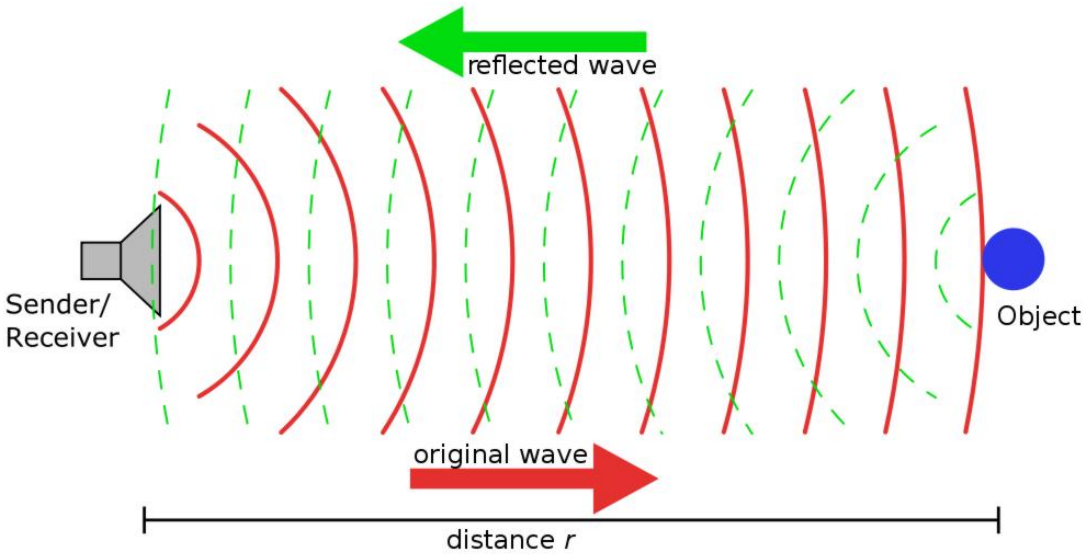


Figure 2.4: Pulse-echo technique

The distance r travelled by the sound wave can be computed. The formula is given by:

$$r = \frac{ct}{2}$$

Where

- r: distance travelled
- c: speed of sound
- t: time of flight, from the transmitter and back to the receiver

This distance r is of the main interest of this project, knowing this distance allows us to be able to know the level of liquid in a tank or simply to know the distance that a certain objects stands from the system.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

The project begins with a very thorough research through books in the areas of radar, sonic and ultrasonic as well as through previous technical papers related to the project in this paper describes.

Next it came the simulation phase, where the LTSPICE simulator from the (…need to complete the name of the company) was used to design the various circuits that will be designed in hardware to achieve the objective of the project: to design an ultrasonic level measurement device. The simulator helps to see what will be the outcome of the design before it is designed, which makes it very important tool to use in all aspects of the electrical engineering work.

The first design made from the LSPICE is the Wein-bridge oscillator. Through the simulation is possible to come up with all the parts that are required to make the oscillator outputs the required 40 KHz frequency sinusoidal waves, such parts as potentiometers, diodes, capacitors, operational amplifiers and resistors.

The next part was to come up with the model of the piezoelectric sensors that is used in this project to send and receive the ultrasonic pulse waves. The model which encompasses resistor, inductor, and two capacitors, is in the form of a resonator with centre frequency of approximately 39 KHz.

Another part of the whole design that needed to be simulated first in the LTSPICE before the hardware design comes into place, is the transistor switch which handles the ask of allowing and blocking the passage of the sinusoidal waves from the oscillator to the transmitter. The simulation of which is important, since is possible to see whether the design criteria that is being used is realistically possible to employ it.

Finally the receiver circuit is also simulated. The receiver circuit is made up by an inverting amplifier, a peak detector and a comparator that converts the received signal into pulses readable by the microcontroller.

3.2 Project Work

The design project encompass many different stages, each one intended to bring on the whole project its value that will support a well and functional project.

Below is the Flow chart of the work:

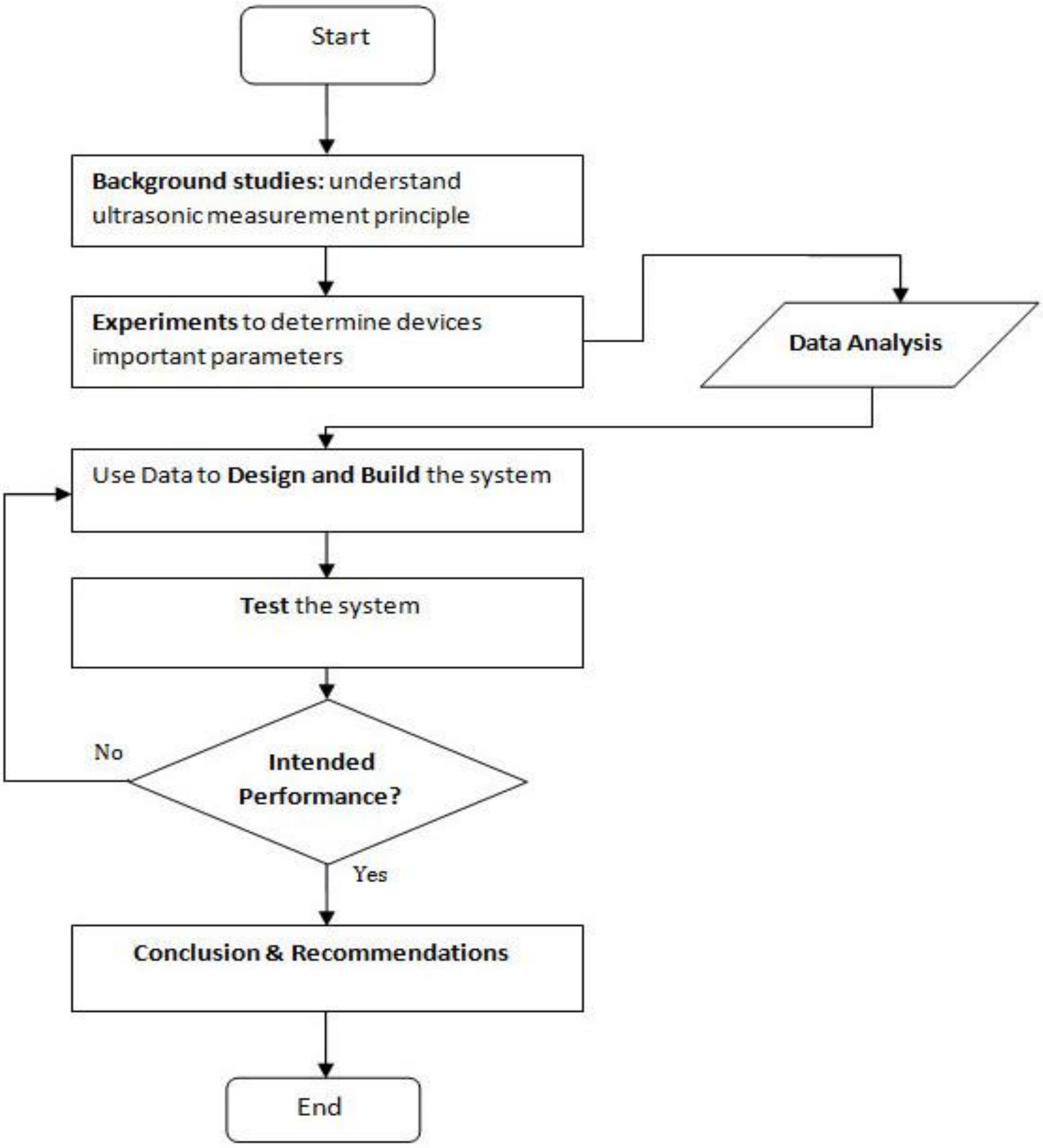


Figure 3.2: Flow chart of FYP Methodology

3.3 Tools Required

Equipments needed for this project are:

i. Atmel ATMega328

ii. 400ST160/400RS160 Ultrasonic transmitter/receiver pair

iii. 16x2 LCD

iv. Printed circuit board

v. 3x TL072 operational amplifier

vi. 3x LM741 operational amplifier

vii. 4x LM358 operational amplifier

viii. Push buttons/switches

ix. Crystal oscillator

x. 5K potentiometer

xi. Resistors, capacitors and diodes

3.4 Project Planning

Project planning: Gantt chart (FYP 1)

Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Research														
Extended Proposal														
Project work continues														
Data Analysis														
Equipment Evaluation														
Interim Report														

Key Milestones:

i. Submission of Extended proposal

ii. Equipment analysis

iii. Interim report submission

Project Planning: Gantt chart (FYP 2)

Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Simulation/Design	■	■	■	■	■	■	■								
Progress Report								■							
Hardware Design									■	■	■	■			
Pre – EDX											■				
Technical Paper													■		
Viva														■	
Submission of Dissertation															■

Key Milestones:

i. Progress Report

ii. Pre- EDX

iii. Technical report

iv. Dissertation submission

CHAPTER 4

RESULTS AND DISCUSSION

WORKING PRINCIPLE OF LEVEL MEASUREMENT

The proposed method for this project is to implement the time-of-flight (TOF) method.

In the TOF method, a pulse (or pulses) is generated and propagates through a transmission medium (air for this project) and gets reflected by some sort of reflector (water surface for this project). The time taken for the pulse to propagate from the transmission site to the reception site is used to determine the distance between the reflector (water surface) and the transducer.

The distance is calculated based on the formula below:

$$D = \frac{c * TOF}{2}$$

Where c, is the sound velocity, given by 331m/s^2.

With this method, errors such as amplitude degradation of received signal can be encountered. Filters can be used to eliminate or reduce noise in the received signal so that a proper time measurement takes place in the microcontroller.

The design of this project is according to the figure below. It will be made up by one, microcontroller (Arduino ATmega328), a Wein-Bridge oscillator, a transistor switch, an amplifier, an envelope detector, a comparator, and the transducer.

Each of these parts will be discussed in part for the pages that follow and the assembling of each one of them follow the diagram given below:

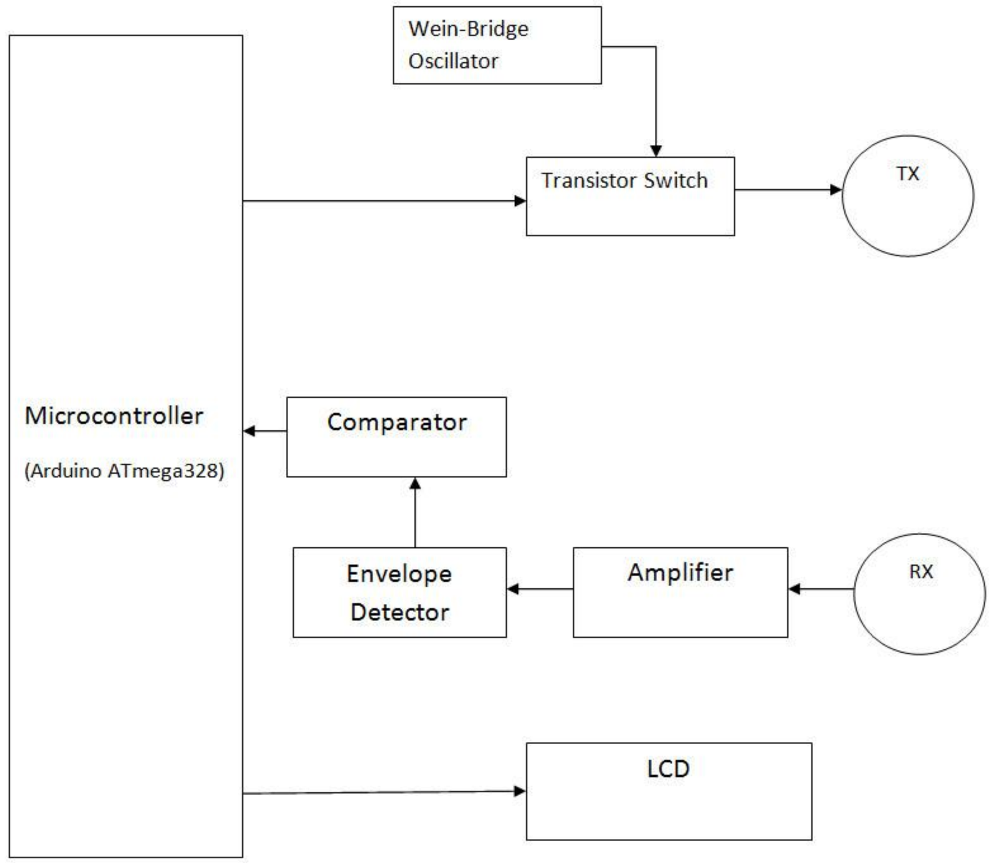


Figure 4: Block diagram of the project

4.1 Transmitting Unit

4.1.1 Wein-Bridge Oscillator Design

The Wien-Bridge oscillator is used in this project to generate the 40 KHz sinusoidal waves. The Wien-Bridge oscillator is a sinusoidal oscillator that consists of amplifiers with two RC circuits that have adjustable oscillation frequencies. The Wien-Bridge oscillator operates without an externally applied input signal. The amplitude and frequency of the spectrum are set by arrangement and value of the components around the op amp.

The figure depicted below is the oscillator designed in the simulator used for this project, the LTSPICE.

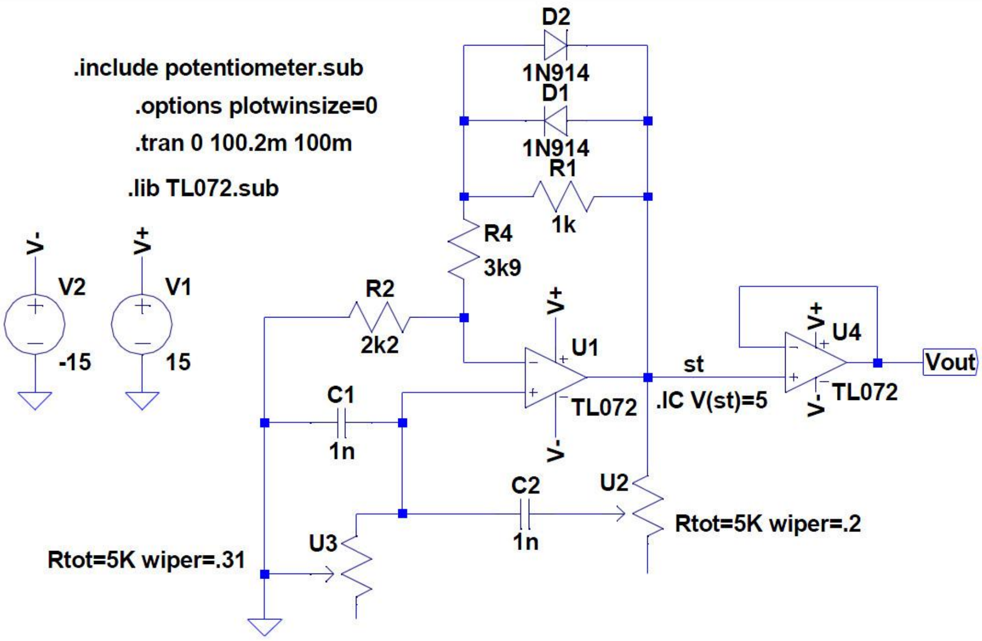


Figure 4.1.1(a): Wein-bridge oscillator (Simulated in LTSPICE)

The Wien-bridge oscillator uses two RC networks connected to the positive terminal to form a frequency selective feedback network. Amplification is obtained through the negative feedback resistors. The operational amplifier used for the oscillator is the TL072 rail to rail (+15V/-15V) operational amplifier from Texas Instrument and the result of the simulation is as below:

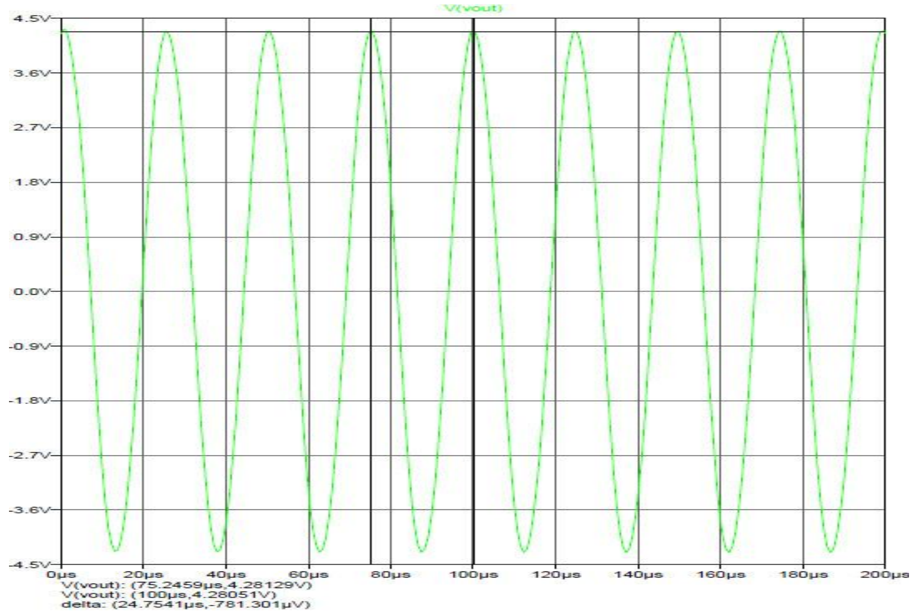


Figure 4.1.1(b): Wein-bridge simulation

Frequency Calculation

There are two ways to calculate the frequency of interest, the first we assume that in the RC network (the frequency selective network) the value of both capacitors is equal, and same goes to the value of the resistors. Therefore, we have the following:

$$f = \frac{1}{2\pi CR}, \quad [Hz]$$

Assuming that $C_1 = C_2 = C$ and $R_3 = R_5 = R$.

The second method, when either $C_1 \neq C_2$ or $R_3 \neq R_5$, the formula that should be used is the following:

$$f = \frac{1}{2\pi\sqrt{(C_1 C_2 R_3 R_5)}}, \qquad [Hz]$$

As it can be seen from fig. 4.2.1, the formula used for this project is the last one, because the values that the potentiometers give are different. Here, capacitors are taken to be of the same value. Hence we have,

$pot_1 = R_3 = 3500\,\Omega$, $pot_2 = R_5 = 4000\,\Omega$ and $C_1 = C_2 = 1\,n$F. Thus,

$$f = \frac{1}{2\pi\sqrt{[(3500)(4000)(1n)(1n)]}} \cong 42.5\ KHz$$

It is important that not the resulting frequency is high than our desired 40 KHz, but this is just theoretical value, meaning the 42.5 KHz it is the ideal value obtained by using the values stated above. The actual value observed through the simulation of the circuit is 40.4 KHz, which is the right value that we need to use on our sensors.

The choice on the use of potentiometers is due to clipping, if we use higher value resistors on the magnitude of 5k, we will face clipping on the sinusoidal signal, which is not desired, and may give inaccurate results along the way. So potentiometers provide the means to avoid the clipping problem.

Amplifier Gain Calculation

The designed amplifier, the one obtained through the simulation and provided in the report is no-inverting type, with the gain given by:

$$G = \frac{R_1 + R_4}{R_2} + 1$$

For oscillation to be obtained, it is necessary that the gain be maintained at approximately 3.

For the design of this project, the values of the resistors are:

$$R_1 = 1\ K\Omega\,,\quad R_4 = 3.9\ K\Omega\ \ , R_2 = 2.2\ K\Omega$$

And the gain is therefore

$$G = \frac{(1K) + (3.9K)}{2.2K} + 1 = 3.22$$

The two diodes used in the oscillator, D_1 and D_2, they reduce the gain a little if the output tries to become too high.

4.1.2 Quartz Crystal (Transducer) Modelling

The transducer that is being used in this project (see Fig. 4.3.1) can be modelled in the same manner as a quartz crystal, which is basically a series of RLC circuit with another capacitor in parallel (see fig.4.3.2).

Figure 4.1.2(a): Piezoelectric transducers

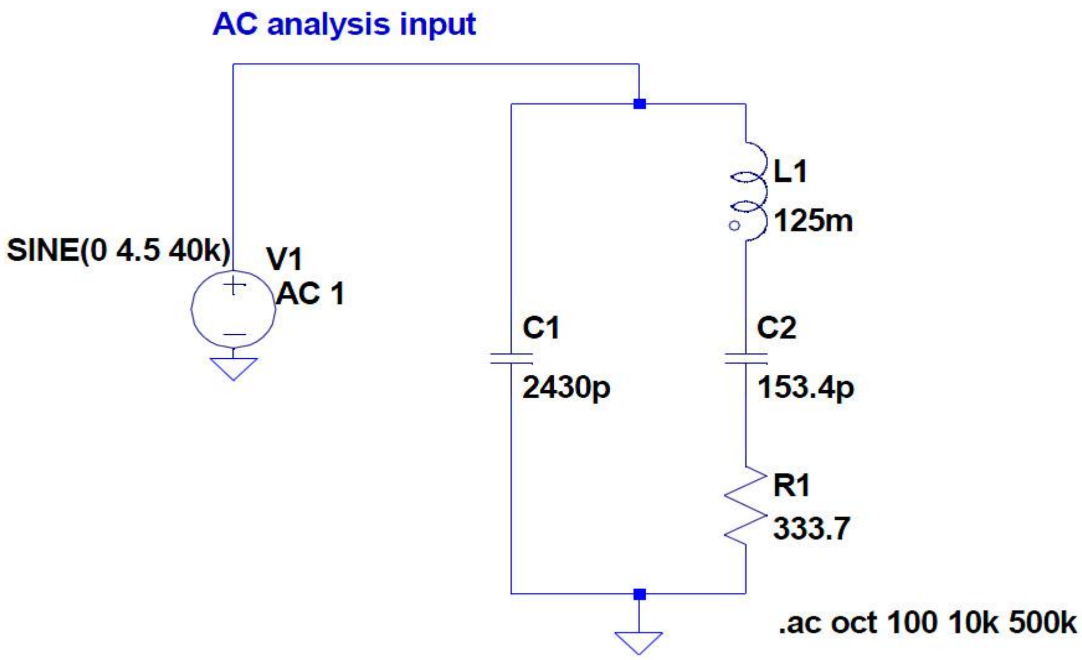


Figure 4.1.2(b): RLC Modelling of the Transducer

The circuit above exhibits series and parallel resonance. Series resonance happens at the frequency where the reactance of inductor and the capacitor are equal. The parallel however, happens when the combination of the inductor L1 and capacitor C2 exhibits an inductive susceptance which resonates with C1.

Running the above circuit in the simulator, the result is as below:

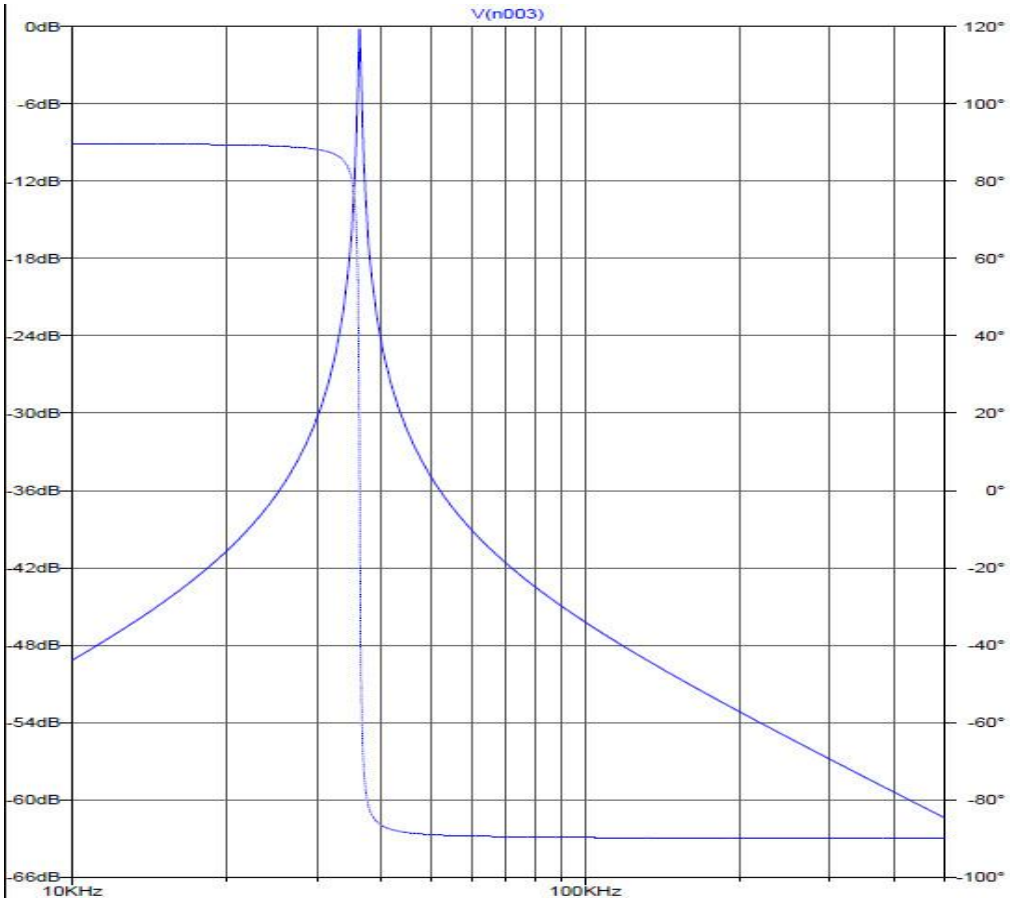


Figure 4.1.2(c): RLC simulation

It is known that the series resonance f_s is given as follow:

$$f_s = \frac{1}{2\pi\sqrt{L_1 C_2}} \ , \qquad [Hz]$$

And using the datasheet for the 400ST160/400RS160 ultrasonic transmitter/receiver pair, we can easily determine the value of f_s to be $f_s = 38.6\ KHz$.

The parallel resonance is given by the following formula:

$$f_p = f_s \sqrt{\left(1 + \frac{C_2}{C_1}\right)}\ , \qquad [Hz]$$

The datasheet also provides us with the means to determine the value of the parallel resonance frequency. That value is $f_p = 39.8\ KHz$.

To design the RLC resonator, we need to determine/calculate the values of R_1 , C_2 and L_1. Normally the value for C_1 is given in the datasheet, and this is 2420 ρF.

Using the formula given above for f_p , we can derive a formula to calculate the value of capacitor C_2.

$$C_2 = C_1\left[\left({f_p}^2/{f_s}^2\right) - 1\right]$$

Substituting the value of C_1 , f_p and f_s in the formula above, we have:

$$C_2 = (2420p)\left[\frac{(39.8k)^2}{(38.6k)^2} - 1\right] = 153.4\ pF$$

The inductor L_1 is given by the following formula, which is the result of the formula given for f_s:

$$L_1 = \frac{1}{4\pi {f_s}^2 C_2}$$

Substituting the corresponding values for the variables, we have:

$$L_1 = \frac{1}{4\pi(38.6k)^2(153.4p)} \approx 125\ mH$$

R_1 Is given by $R_1 = 362\cos(-22) =\ 333.7\ \Omega$

4.1.3 Transistor Switch

An analog switch CD4066 is used to allow the sine wave from the Wein-bridge oscillator to the transmitter. The switch is digitally controlled by the Microcontroller. As the switch can only pass positive voltages, the sine wave from the oscillator is given a DC shift.

4.1.4 Microcontroller

The Microcontroller chosen to be used in this project is the ATmega328. It is a high-performance Atmel 8-bit AVR RISC-based microcontroller which combines 32KB ISP flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general purpose I/O lines. It performs the operation of giving the switching signal, computing the distance and displaying the result in the LCD. It operates between 1.8-5.5 volts.

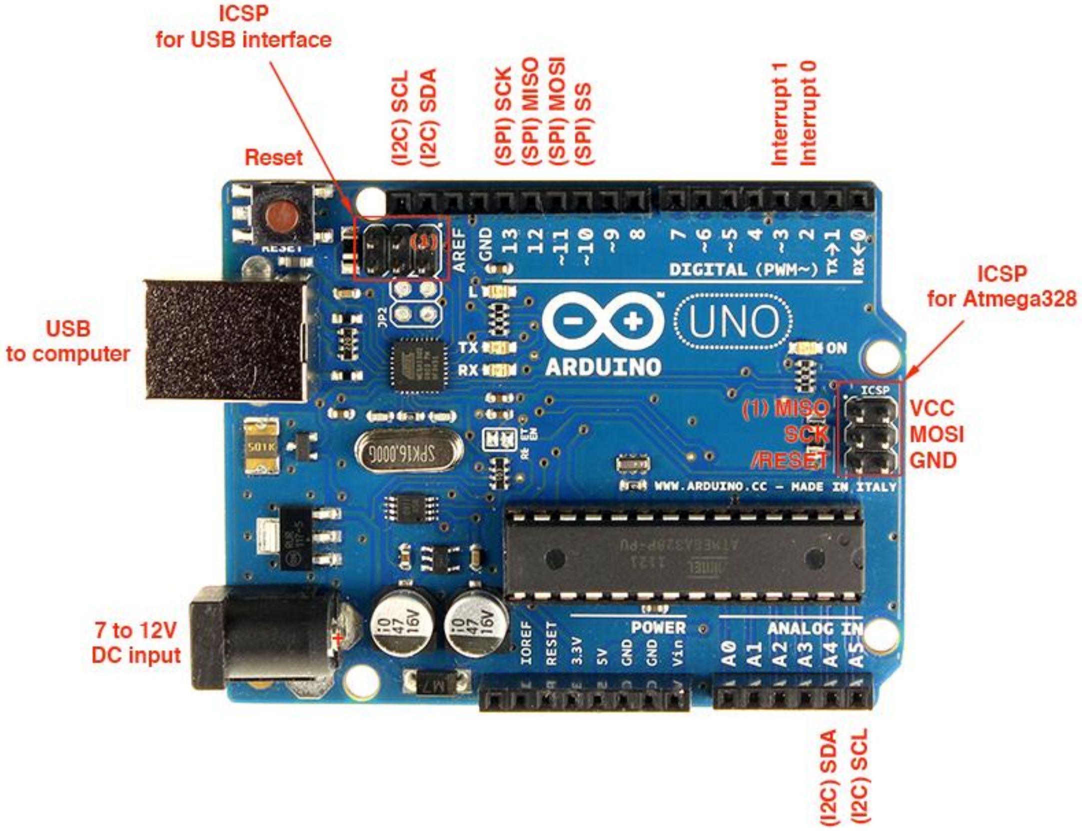


Figure 4.1.4(a): Arduino Uno

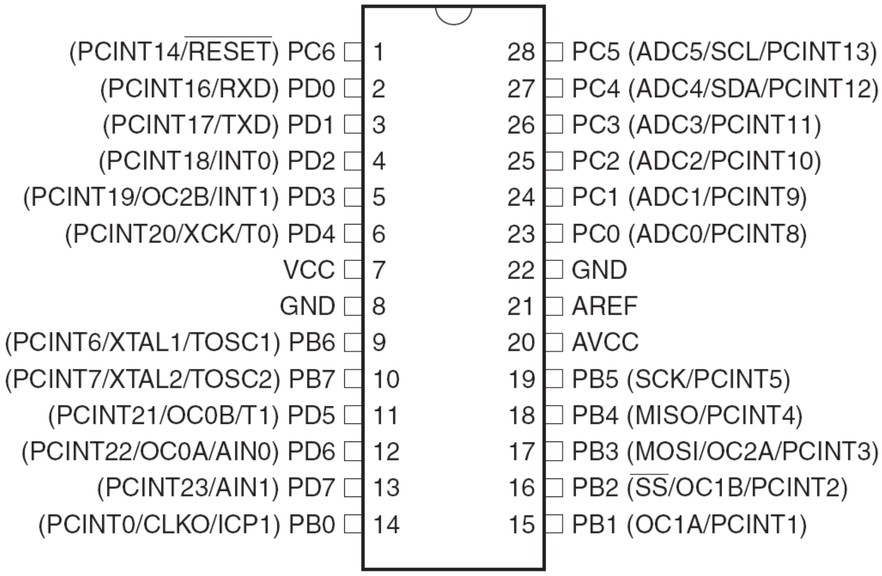


Figure 4.1.4(b): ATmega328 chip

4.2 Receiver Unit

The receiver unit is made up by an amplifier, a peak detector and a comparator. The circuit from the simulation and shown below:

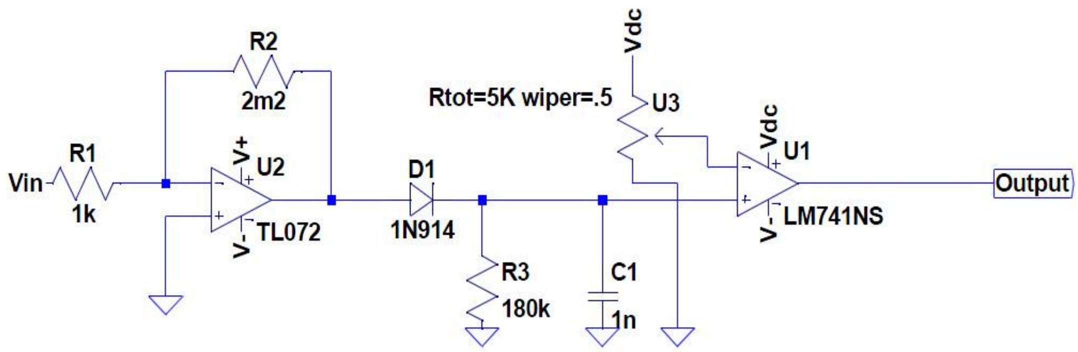


Figure 4.2: Receiver circuit

4.2.1 Amplifier

The frequency of the received signal is 40 KHz, and therefore requires amplifiers working at high frequencies. The TL072 is used, as it has high frequency gain characteristics. The gain of the amplifier is 2200 set by one stage.

4.2.2 Comparator

The output signal from the amplifier is passed through the comparator which compares with a reference threshold level to get rid of unwanted and false triggering. The signal is a series of square pulses with amplitude of 5 volts. This in turn is passed through a protective diode to be fed to the Microcontroller for counting the pulses.

4.3 Description

The project on Ultrasonic works by emitting a signal at 40 Khz using a transmitter. The transmitted pulse will refletct through the surface of the liquid and it will be detected by the receiver.the difeerence between the sending and receing of the pulse will determine the distance and thus the level of the liquid.

The Microcontroller provides the control, and timing calculations. It is the microcontroller that sets the start and stop time of the sending pulse, as well as the delay between each pulse, which will trigger the Wein-Bridge oscillator to send a pulse to the transmitter. At the receiving end, the receiver receives the transmitted pulse, where it will go through the amplifier, then the envelope detector and before it is processed by the microcontroller it will be sent to the comparator to be converted to digital signal.

4.3.1 Firmware Description

The Microcontroller closes the switch for a duration of 200 microseconds to allow 8 cycles of 40 KHz pulse wave. It waits to receive the pulses for a maximum duration of 20 milliseconds. This is the time taken for ultrasound waves to travel a maximum distance of 5 meters (Sensor espcification in Appendix B).

The flowchart of the program is given below:

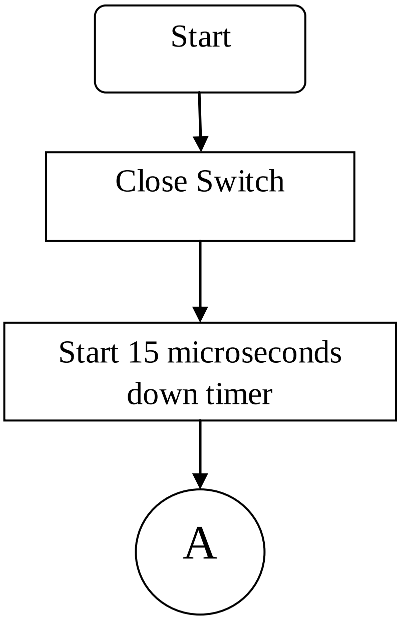


Figure 4.3.1(a): Flowchart of the Program

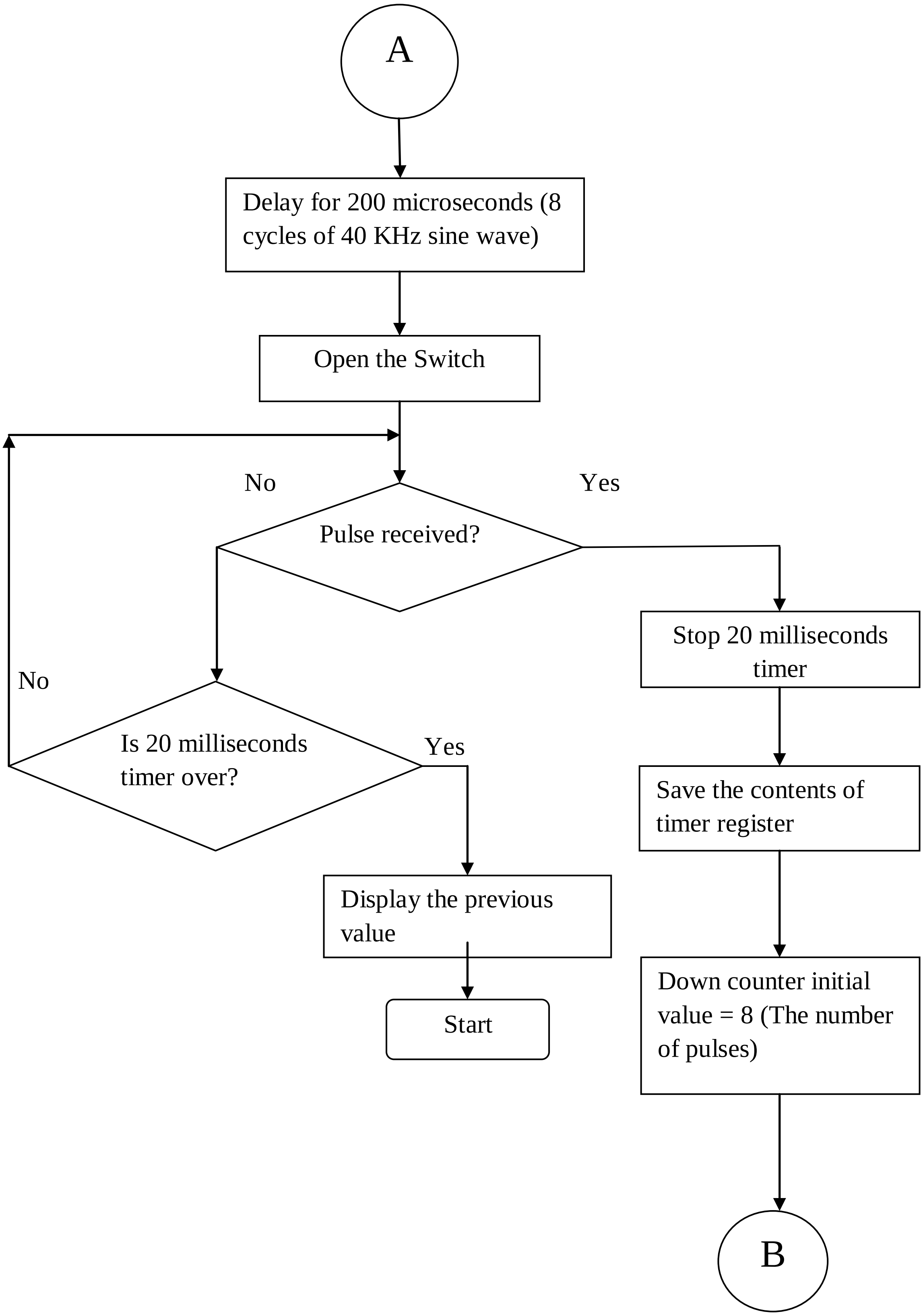


Figure 4.3.1(b): Flowchart of the Program

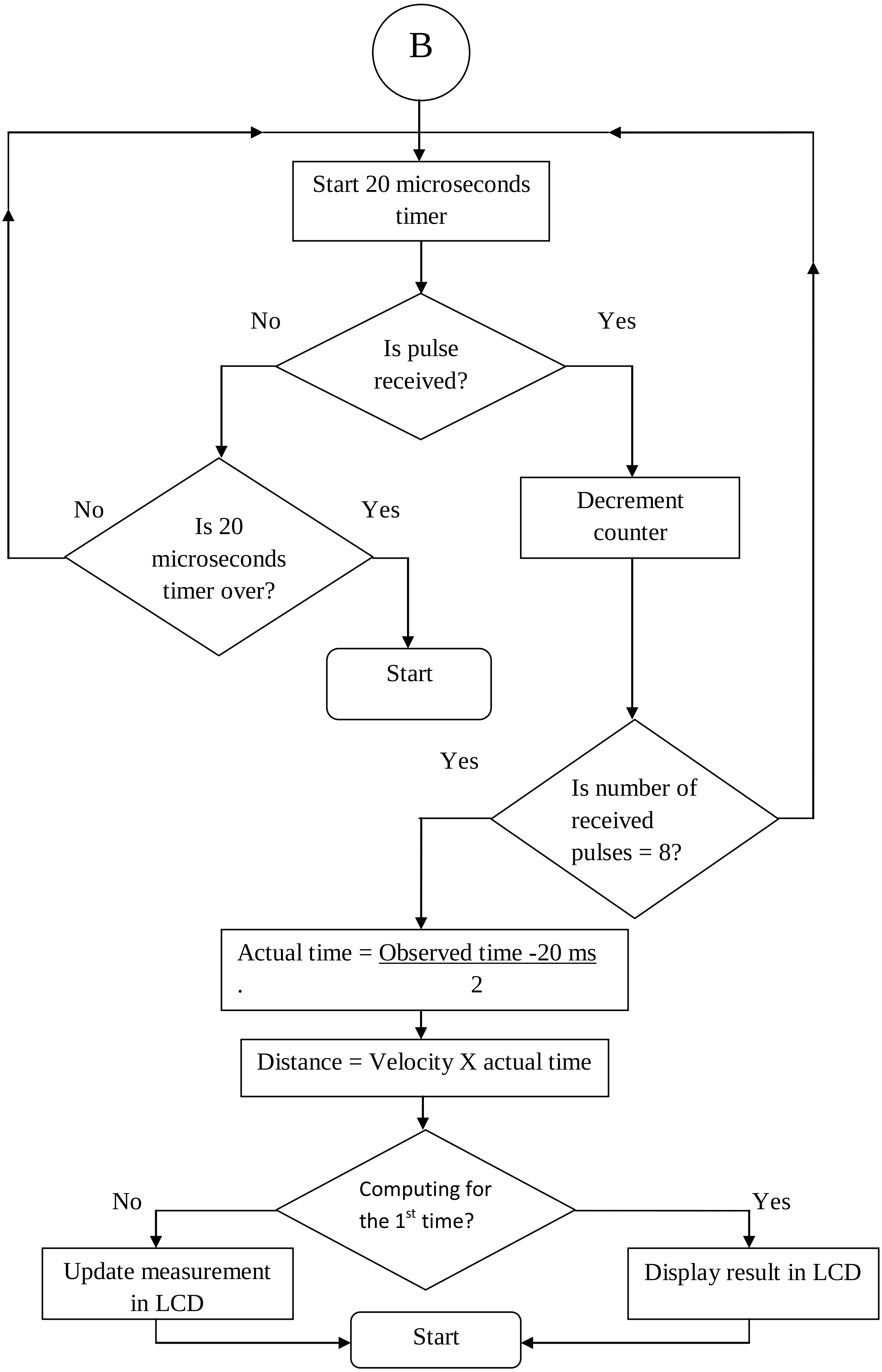


Figure 4.3.1(c): Flowchart of the program

The complete program that sends the signal to the transmitting circuit and also to calculate the distance using the information from the receiving circuit is given in the appendix A.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The project on Ultrasonic liquid-level measurement is better employed when a Microcontroller is used to take on the task of control and calculation of distance, which takes very short time to do those tasks. For that, the ATmega328 was chosen for this project, as it is user-friendly and easy to program.

The signal design is very important, since is because of it that we will be able to know for sure what to expect from the design or project that we are going through with. The accuracy, the range and the frequency, as well as the voltage of the signal to transmit, are very important factors that should not be taken lightly.

The simulation part is complete and the next phase which is the hardware part is almost complete.

With the designed circuit and the program for the microcontroller, it was possible to measure up to 3.5 meter of distance.

5.2 Recommendations

Using wein bridge oscillator is one of the many methods that can be used to generate waves to be fed to the transmitter transducer. But using this method, requires a little complicated circuitry because a comparator needs to be used is a pulse wave is to be used. One way to simplify this is by using a 555 timer pulse generator, which is also known as astable multivibrator. This will not only simply the circuitry itself, but will also minimize the cost of the entire system.

Other than using either a wein bridge oscillator or an astable multivibrator to generate the signal of interest, it is also possible to generate the signal using the microprocessor (Arduino uno). This further reduces the hardware, but a especial circuitry will need to be designed to receive the generated signal from the microprocessor and be able to drive the transmitter transducer.

For this project filtering relied on the peak detector, but this sometimes is not enough when using the designed project in environments where disturbances occur which may interfere with the echo of the transmitting signal, this then jeopardizes the microprocessor in reliably determining the time the signal takes to travel and therefore may resulting in giving inaccurate distances. To solve this problem it is recommended that Match filtering be used, as it is very reliable in increasing the signal to noise ratio of the signal, which helps in environments where signal strength may be attenuated.

The system described in this report can be used not only in level measurements in tanks, but can also be used in the coast, where the rise and fall of the sea water is important to be constantly monitored.

REFERENCES

1. NDT Resourse centre. In *Wave Propagation*. Retrieved june 26, 2012, from http://www.ndt-ed.org/EducationResources/CommunityCollege/Ultrasonics/Physics/wavepropagation.htm

2. The Physics Classroom. In *The Nature of a Sound Wave*. Retrived june 26, 2012, from http://www.physicsclassroom.com/class/sound/u11l1b.cfm

3. Marvin C. Ziskin (1993). In *Fundamental Physics Of Ultrasound and Its Propagation in Tissue.*

4.Mike Stracey.Mike's cybot page. In Sensors.Retrieved June 25, 2012, from http://www.mstracey.btinternet.co.uk/technical/Theory/theorysensors.htm

5. Esnminger, D (1988). Ultrasonics: Fundamentals, Technology, Applications. New York: Mercel Dekker.

APPENDICES

APPENDIX A

Project Program

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

int pingPin = 13;
int inPin = 10;
 void setup() {
lcd.begin(16, 2);
lcd.print("testing...");
}
 void loop()
{
  // establish variables for duration of the ping,
  // and the distance result in centimeters:
  long duration, cm;
   // The PING))) is triggered by a HIGH pulse of 2 or more microseconds.
  // Give a short LOW pulse beforehand to ensure a clean HIGH pulse:
  pinMode(pingPin, OUTPUT);
  digitalWrite(pingPin, LOW);
  delayMicroseconds(2);
  digitalWrite(pingPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(pingPin, LOW);
```

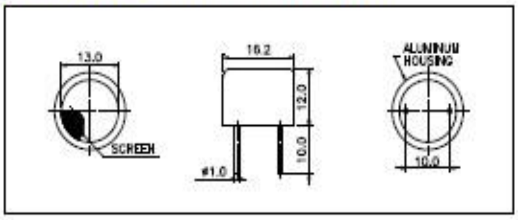
```
  // The same pin is used to read the signal from the PING))): a HIGH
  // pulse whose duration is the time (in microseconds) from the sending
  // of the ping to the reception of its echo off of an object.
  pinMode(inPin, INPUT);
  duration = pulseIn(inPin, HIGH);

  // convert the time into a distance
  cm = microsecondsToCentimeters(duration);
  lcd.clear();
  lcd.setCursor(0, 0);
  //lcd.print(inches);
  //lcd.print("in, ");
  lcd.print(cm);
  lcd.print("cm Distance");
  lcd.setCursor(0,1);
 lcd.print("From the sensor");
   delay(100);
}
long microsecondsToCentimeters(long microseconds)
{
  // The speed of sound is 340 m/s or 29 microseconds per centimeter.
  // The ping travels out and back, so to find the distance of the
  // object we take half of the distance travelled.
  return microseconds / 29 / 2;
}
```

APPENDIX B

<u>Sensors Datasheet</u>

Air Ultrasonic Ceramic Transducers 400ST/R160

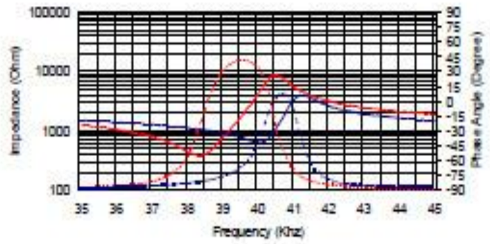
Dimensions: dimensions are in mm



Impedance/Phase Angle vs. Frequency

Tested under 1Vrms Oscillation Level

400SR160 Impedance
400SR160 Phase
400ST160 Impedance
400ST160 Phase

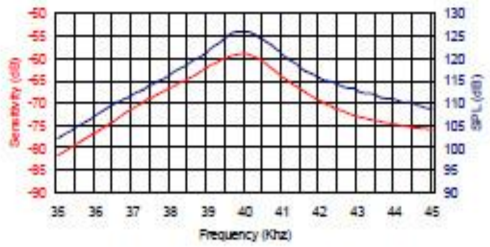


Specification

400ST160		Transmitter
400SR160		Receiver
Center Frequency		40.0±1.0Khz
Bandwidth (-6dB)	400ST160	2.0Khz
	400SR160	2.5Khz
Transmitting Sound Pressure Level at 40.0Khz; 0dB re 0.0002μbar per 10Vrms at 30cm		120dB min.
Receiving Sensitivity at 40.0Khz 0dB = 1 volt/μbar		-65dB min.
Capacitance at 1Khz ±20%		2400 pF
Max. Driving Voltage (cont.)		20Vrms
Total Beam Angle -6dB		55° typical
Operation Temperature		-30 to 80°C
Storage Temperature		-40 to 85°C

Sensitivity/Sound Pressure Level

Tested under 10Vrms @30cm



Beam Angle: Tested at 40.0Khz frequency