Development of Sonar Sensor System for Autonomous Underwater Vehicles Application

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Abstract - **This project is about the development of sonar sensor system in purpose for Autonomous Underwater Vehicles (AUV) application. The concept of this project is using the ultrasonic sensor as a main device to transmit and receive the signal from the obstacle. The ultrasonic sensor will be combined to the ultrasonic circuit. Usually, the ultrasonic sensor is often used in robots for obstacle avoidance, map building and especially in navigation. Ultrasonic range sensor is works by emitting a short burst of 40 kHz sound. In addition, a small amount of sound energy is reflected by objects in front the device and returned to the detector or the receiver. The receiver sends this reflected signal known as echoes to the microcontroller to determine how far away the objects. However, to know how far away the objects it is using the speed of sound and time it took for the signal to be reflected. Unfortunately, echoes are not completely a product of distance. Different the medium will give the different speed and different result. It uses a Proowave Ultrasonic TXR and MikroC software as a compiler.**

Keyword- **Ultrasonic sensor; Sonar sensor, Echoes**

I. INTRODUCTION

A sonar sensor is actually a device that used to transmit and to receive a signal from the obstacle [1]. In other words, sonar is a short term that taken from the 'Sound Navigation and Ranging' [2]. A sonar sensor is essentially an inexpensive device. Nowadays, the sonar sensor are widely use in over the world for the specific purpose. Many project and research are building up based for the purpose of the Autonomous Underwater Vehicles (AUV). This is because, sonar sensor has its own special characteristic and waterproof that can penetrate in any type of water [8]. However, the microcontroller will do the job by giving a command to the sonar sensor to work. The suitable programs should be creating based on the objective of the project.

II. DESIGN METHODOLOGY

This chapter consists on detailed discussion of the methodology. It is divided by two important sections. The first section is project design flow on hardware process and the second is about project design on software that include in the development of sonar sensor system for Autonomous Underwater Vehicles (AUV) project. After that, the two separate design flow should be combine to make the system operate. The design flowchart should be design clearly according to the objective of the project. This is very important to make sure that all the work can flow smoothly and can minimize the problem. All the hardware and the software that include in the project should be considered before start the design flow chart. Referring on the Figure 1, the hardware development project consists of two separate things.

The first is about PIC training kit circuit and the second is ultrasonic distance circuit. For the PIC training kit circuit is needed in this project as a microcontroller. Test the PIC training kit circuit is very important to know either the circuit is function well or not. For the PING ultrasonic distance circuit, the test of functional is really important also. This is because to make sure that this circuit is operate in well condition. The method that use to test either this circuit can work well or not is by using the already circuit without replaced the Proowave Ultrasonic TXR sensor. If the circuit can work well and can give the accurate distance base on the theory, then it's needed to replace the already sensor by using the Proowave Ultrasonic TXR sensor. Then, the systems are run after the combination of complete hardware and software part. The Proowave Ultrasonic TXR on the system that developed will put on the water manually. By measuring the echo pulse width by the microcontroller, the distance to obstacle or the object will display on the LCD at the PIC training kit part. The LCD will display the actual distance from the ultrasonic sensor to

the obstacle. After that, it is need to design a simple prototype of AUV. The design can be done by using Solid Work software. Then, a suitable material for AUV must be fabricated. The system that developed can place on the prototype of AUV that build at a suitable position.
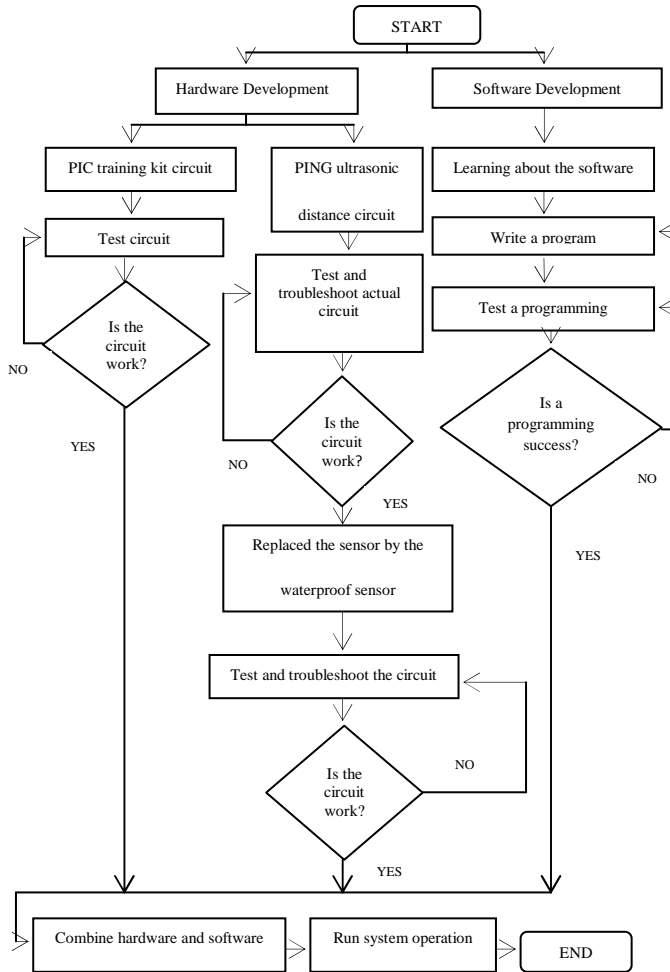

Figure 1: Flow Chart of Combination of Hardware and Software Project Design

III. BASIC OPERATION

Ultrasonic is sound with frequencies above 20 kHz. Since the sensor that use in this project is at 40 kHz, they are definitely ultrasonic and not audible [7]. Before start the project, it necessary to know the basic of the operation the hardware or the software. The main hardware that needed in this project is ultrasonic sensor while the software that need is this project is mikroC function as a compiler. Basically, the microcontroller tells the ultrasonic sensor to go. Then, ultrasonic sensor emits a mostly inaudible sound; time passes, and then detects the return echo [10]. It then immediately send a voltage signal to the microcontroller,
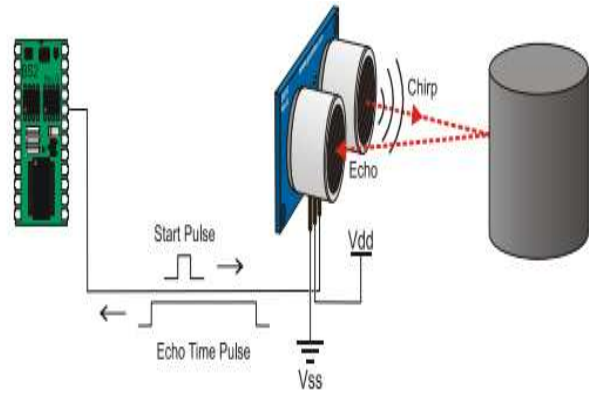
which by keeping track of the time that passes and calculate the distance of the objects detected. Figure 2 shows the connection of the hardware that involved in this project development.

Figure 2: The connection of the hardware

A. Communication Protocol

Figure 3 shows the waveform of the ultrasonic sensor on the operation. The ultrasonic sensor detects objects by emitting a short ultrasonic burst and then "listening" for the echo [5]. Under control of a host microcontroller (trigger pulse), the sensor emits a short 40 kHz (ultrasonic) burst. This burst travels through the water, hits an object or the obstacle and then bounces back to the sensor [5]. The ultrasonic sensor provides an output pulse to the host that will terminate when the echo is detected, hence the width of this pulse correspond to the distance to the target. Table 1 shows the communication protocol.
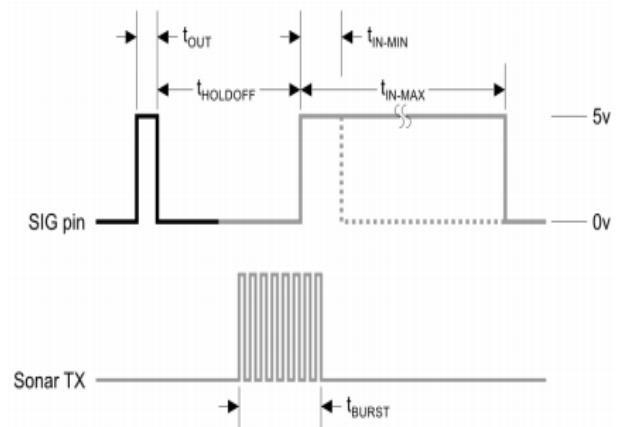

Figure 3: Waveform of Communication Protocol.

TABLE 1.
THE COMMUNICATION PROTOCOL

	Host device	Input Trigger Pulse	t_{OUT}	2us (min),5 us typical
	Ultrasonic Sensor	Echo Holdoff	$t_{HOLDOFF}$	750 us
		Burst Frequency	t_{BURST}	200 us@ 40 kHz
		Echo return Pulse Minimum	t_{IN-MIN}	115 us
		Echo Return Pulse Maximum	t_{IN-MAX}	18.5 ms
		Delay before next measurement		200 us

B. Object Positioning

Not all the position of the object can measure by the ultrasonic sensor system. Figure 4, 5 and 6 shows the object positioning. The ultrasonic sensor cannot accurately measure the distance to an object that are is more than 3 meters, that has reflective surface at a shallow angle so that sound will not be reflected back towards the sensor and is too small to reflect enough sound back to the sensor.
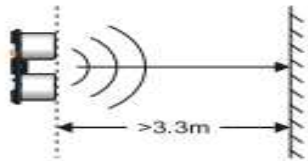

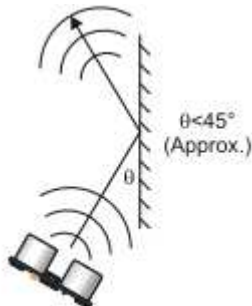Figure 4: The distance of obstacle and the sensor is more than 3 meters.

Figure 5: The angle of obstacle and the sensor is less than 45°.

Figure 6: The object that detecting by the sensor is too small.

In addition if the speed of sound in the water and time taken are known, then the distance are easily calculate by the formula that shown below. The reason why the time taken is need divided by two because, the signal needs to travel from the transmitter and going back to receiver. Equation 1 shows how to calculate the distance from the object [4].

$$\text{Distance} = \text{Speed of sound} * (\text{Time passed}/2) \qquad (1)$$

IV. RESULT

This session will be discussed about the results that have been done for development of sonar sensor system for AUV Application project. First of all, study on the back ground of suggested project. After that, search and get information about the main hardware use in this project. Then, find the datasheet and get the information of the main component use in this project such as PING Ultrasonic Distance Sensor, Proowave Ultrasonic TXR and PIC 16F877A. The Figure 7 shows the PING Ultrasonic Sensor Distance circuit. The PING sensor has a male 3-pin header that function used to supply ground, power and signal. The header may be plugged into a directly into solderless breadboard, or into a standard 3-wire extension cable. Refer to the Figure 8 shows the pin definition of PING ultrasonic distance sensor circuit. Table 2 refers the pin definitions of the circuit.
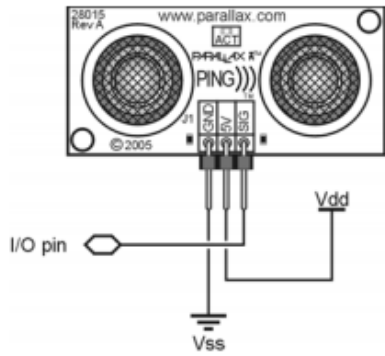

Figure 7: PING Ultrasonic Sensor Distance

Figure 8: Pin Definition of PING Ultrasonic Distance

TABLE 2.
PIN DEFINITIONS

GND	Ground (Vss)
5V	5 VDC (Vdd)
SIG	Signal (I/O pin)

A. Developed a Controller Board and Ultrasonic Distance Circuit

Based on the project, the controller board for PIC16F877A is developed. The board is divided into 2 sections which are; the burner section and the controller section. All the distance that detected by the ultrasonic sensor will be displayed on the 2x16 LCD that already attached to the microcontroller board. The size of this board is about; 10cm X 30 cm. Figure 9 shows the circuit of controller board.
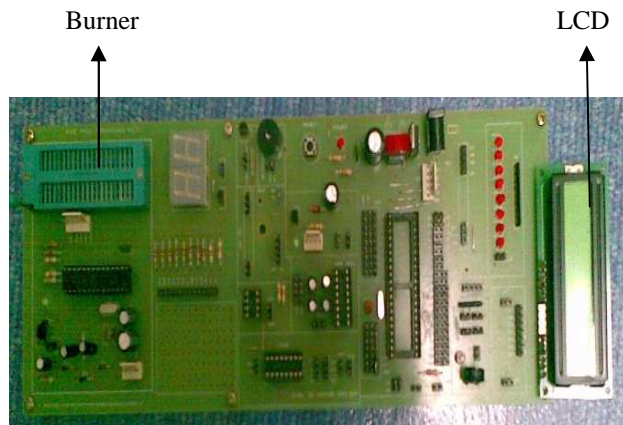

Figure 9: Circuit of controller board.

Then, the microcontroller part will be combined with the ultrasonic distance sensor circuit. The ultrasonic sensor will be replaced with the proowave ultrasonic TXR sensor. Figure 10 shows the proowave ultrasonic TXR sensor.
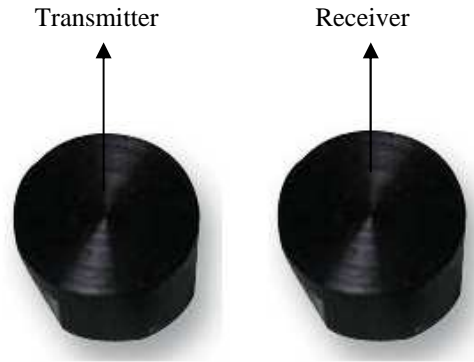

Figure 10: Proowave Ultrasonic TXR

B. Design a Flow Chart of Program.

Before start write a program, it is compulsory to design a flow chart based on the program. The purpose to do that is to make sure that the yield of the program is correct. Figure 11 shows of the flow chart of the program.
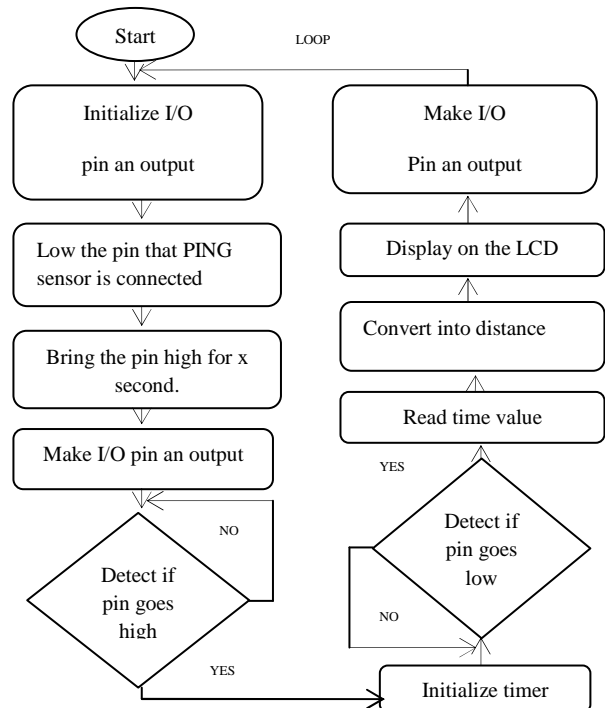

Figure 11: Idea the Flow Chart of the Program

C. Prototype of AUV, Ultrasonic Distance Sensor and Controller Board Position.

Figure 12 shows the design of the prototype AUV with the position of the sensor and controller board. Refer to the Figure 12, the transmitter and receiver sensor are located at the bottom inside the AUV prototype. Then, the controller board will be place beside the sensor location in a short distance to minimize the usage of wire connection and also can reduce the power loss. Figure 13 and 14 shows the real AUV that will be attached with sonar sensor system.
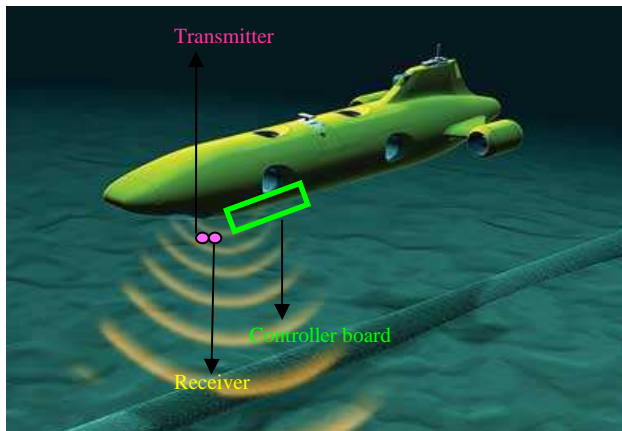

Figure 12: Prototype of AUV

Figure 13: An AUV (top view)

Figure 14: An AUV (side view)

V. CONCLUSION

From this project, a lot of thing that can be learn about the sonar sensor system. Students will be able learn the main theoretical of the sonar sensor system work for underwater. Besides that, student will be able learn how to make a connection of the hardware that use in this project. For the example, the connection between the PIC microcontroller and the ultrasonic sensor distance circuit. In addition, student also knows how to use the PIC16F877A. The programming that used MikroC as a compiler will make the students more advanced and more understand how to build a program by using this software. Other things after carry out this project, it can expand the knowledge on wavefront propagation. The designing of the prototype of AUV need to use a SolidWork at a first stage make a student learn a new software that are really important in engineering field.

ACKNOWLEDGEMENT

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