ULTRASONIC RANGE METER USING PIC16F873A MICROCONTROLLER

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MAY 2008

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronics and Drives)"

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Date : 07 / 05 / 2008

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"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

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ABSTRACT

The purpose of this project is about to design and build a device that using the ultrasound, which one of the ways of measuring distance. This about that can be measured by standing just at one place which means no need to measure for along the distance. This gives benefit in saving time and energy during measuring the distance. This device which the ultrasonic sensor is used and it is separates into the two kinds, the transmitter and the receiver. Both this sensor is used to transmit and receive the 40 kHz ultrasonic signal that used to measure the time. This Ultrasonic Range Meter detects a reflected wave from the object after sending out an ultrasonic pulse. The detection is done to detect the received ultrasonic signal. The microcontroller, PIC16F873 is use as interfacing to the output display. By measuring the time which returns after emitting a sound wave, a distance to the object is measured. This project gives the improvement on reading technique compare by measure the distance manually. Basically, this project is separate into three main parts. The first one is to finds and designing the hardware that required and related to the project, the second part is to construct and develop the hardware together with testing and troubleshooting. Then the third is designing and develop the software part and combine together with the entire of hardware component developed. In this project, the main electrical and electronic component is use including ultrasonic sensor module, PIC Microcontroller and also Liquid Crystal Display (LCD). This priority of this project is to improve the distance measuring technique to be more easier and saving time and give another benefits and soon the conception of this project could be apply to other applications such as distance detector for car reverse or parking sensor and also for robotic range finder.

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CHAPTER 1.0

INTRODUCTION

1.1 Overview

All kinds of devices or equipments nowadays, begins with the basic design with the basic theory and then all the weakness followed by improvement step-by-step. So this project also do right the same reason which the improvement will be applied to bring the advantages to the user when measuring the distance depending on several problems that had been identified. The problems occurs from the current product that one will be improvement soon is identified by covering some factors likes the functionality, reliability, and also safety besides covering on cost so that the aim of why this improvement is carry out will be achieve.

Generally, this project is developing due to improve the measurement technique become easier, more effective and reliable to the distance reading result through a device with ultrasonic deflection wave technology. What the most important purpose of why this project is being carry out is the ultrasonic technology that used for this project is one of the medium on how the distance will be measure and this is one of the ways that the world today widely used especially in some kind of general application such as in warfare applications, engineering applications and also in scientific and medical applications.

Basically this ultrasonic technology is came from and based on ultrasound and a common use of ultrasound is in range finding that perfectly related to the objectives of this project. 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, medical ultrasonography, burglar alarms, and non-destructive testing. By all this application, this ultrasonic technology is suitable for this improvement of this project in measuring the distance.

1.2 Problem statement

Usually the distance measurement mostly had been carried out manually such as using measurement tape. By this method, there are several problems that occur during measurement activity and could affect the result at the end. The most problems that identified for this project are:

- The non-accurate reading taken from distance measurement
  - Know that the accuracy of the reading will be affected when the long distance had been taken. Typically by using the measurement tape, the user should take at least 3 time of reading result to have the average of result in order to have the accurate reading of distance measurement.

- Time taken during the distance measurement process.
  - Practically, when the reading is taken frequently to get the accurate result, the time that taken to carry out that result also will be affected. That mean measure the distance manually using measurement tape is quite wasting time and energy as well as.

- Safety of injury during handling the measurement devices/tools
  - When handling any devices or tools especially consist of mechanism compartment's tools, we most facing to the safety of injury. In this case the tools like measurement tape consist of sharp metal tape that always cause of injury and it always happen during to rolling-in that sharp metal tape after the measurement activity is done.

1.3 Project objectives

Point of the whole flow of this project had been classified first to bring out the expected result successfully with considering the statement of the problems that already being identified for this project. So the following project objectives mannerly had been created to make sure the aim of this project will be achieve at in the end:

1. To design a digital range meter using ultrasonic technique that can measure the accurate reading.
2. To generate the ultrasonic signal that needed to measure the distance.
3. To implement PIC microcontroller as a controller circuit that can make the processing data faster.
4. To construct and develop a device to be multi-reading conversion measuring device.
5. To design a device to be implemented to the various application.

1.4 Scope of project

The project final results;

- A developed device that can measure the distance with the accurate reading based on the PIC16F873 microcontroller and able to do the measurement by standing just one site of measurement range.

Approach used in this project;

- Design and develop a method on how to measure the distance by using wave deflection technology (ultrasonic signal).
- Process and develop the solution to calculate the measurement data to have the expected result and PIC16F873 as the controller on calculating the data.
- Compare the result that how far the improvement have been done.

The project involved;

- Hardware;
  - The hardware development consists of the design, redesigns, testing and troubleshoots all the circuit involved.
  - Build up the hardware for every stage of circuit.
  - Assemble the component as well as reducing the cost.

- Software;
  - The software part will base on the simulations and hardware itself for all the project parts on the Ultrasonic Range Meter.

- Firmware;
  - This part consists of programming the software into the PIC microcontroller in hardware site and this combination of hardware and software should bring the expected result successfully that will measure the distance correctly compare to the real distance measurement.

CHAPTER 2.0

LITERATURE REVIEW AND THEORETICAL

2.1 Range, accuracy and error

The measuring distance, measuring interval and range are terms which describe the difference between the lower and upper limits that can be measured. The range ability or turndown is the ratio between the upper limit and lower limits where the specified accuracy can be obtained. The error is a measurement of the difference between the measured value and the true value. The accuracy is the maximum error which can occur between the process variable and the measured value when the transducer is operating under specified conditions. Errors can occur for several reasons such as calibration error, manufacturing tolerances and environmental effects are common. Many devices have an inherent coarseness in their measuring capabilities.

In many applications the accuracy of a measurement is less important than its consistency. The consistency of a measurement is defined by the terms repeatability and hysteresis. Repeatability is defined as the difference in readings obtained when the same measuring point is approached several times from the same direction. Hysteresis occurs when the measured value depends on the direction of approach as Figure 2.1. Mechanical backlash or stiction are common causes of hysteresis. The accuracy of a transducer will be adversely affected by environmental changes, particularly temperature cycling, and will degrade with time. Both of these effects will be seen as a zero shift or a change of sensitivity (known as a span error).

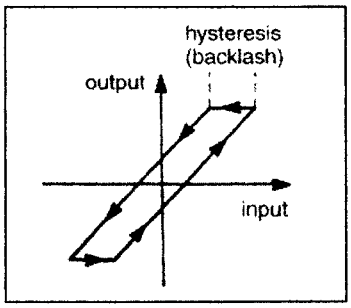

Figure 2.1: Hysteresis, also known as backlash. The output signal is different for an increasing or decreasing input signal

2.2 Ultrasonic Technology

Basically ultrasonic is an adjective referring to the ultrasound and also called SONAR (**SO**und **NA**vigation and **R**anging) is a technique that uses sound propagation under water (primarily) to navigate, communicate or to detect other vessels. There have two kind of SONAR, **active** and **passive.** The term **sonar** is also used for the equipment used to generate and receive the sound. The frequencies used in sonar systems vary from infrasonic to ultrasonic.

Regarding to this project, the main point is refer to the Active sonar with uses a sound transmitter and receiver. When the two are in the same place it is monostatic operation. Active sonar uses a sound transmitter and a receiver. When the two are in the same place it is monostatic operation. Most sonar are used monostatically with the same array often being used for transmission and reception, though when the platform is moving it may be necessary to consider a single transmitter/receiver as being operated bistatically.

Active sonar creates a pulse of sound, often called a "ping", and then listens for reflections (echo) of the pulse. This pulse of sound is generally created electronically using a Sonar Projector consisting of a signal generator, power amplifier and electro-acoustic transducer/array, possibly with a 'beam former'. To measure the distance to an object, the time from transmission of a pulse to reception is measured and converted into a range by knowing the speed of sound. When active sonar is used to measure the distance from the transducer to the bottom, it is known

as echo sounding. Similar methods may be used looking upward for wave measurement.

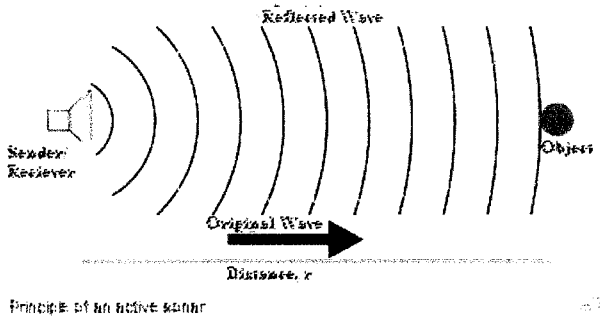

Figure 2.2: Principle of Active Sonar

2.3 Sound propagation

Sonar operation is affected by variations in sound speed, particularly in the vertical plane. Sound travels more slowly in fresh water than in sea water, though the difference in speeds between fresh and salt water is small. In all water sound speed (sometimes called velocity though this is incorrect) is determined by its bulk modulus and mass density. The bulk modulus is affected by temperature, dissolved impurities (usually salinity), and pressure. The density effect is small. The speed of sound (in feet per second) is approximately equal to:

$$4388 + (11.25 \times \text{temperature (in °F)}) + (0.0182 \times \text{depth (in feet)} + \text{salinity (in parts-per-thousand)}$$

This is an empirically derived approximation equation that is reasonably accurate for normal temperatures, concentrations of salinity and the range of most ocean depths.

2.4 Ultrasonic Sensors

Ultrasonic methods use high frequency sound produced by the application of a suitable AC voltage to a piezoelectric crystal. Frequencies in the range 50 kHz to 1 MHz can be used, although the lower end of the range is more common in industry.

The principle is shown on Figure 2.3. An ultrasonic pulse is emitted by a transmitter. It reflects off the surface and is detected by a receiver. The time of flight is given by:

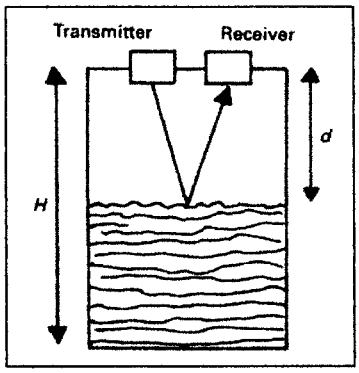

Figure 2.3: Basic arrangement for ultrasonic level measurement

Ultrasonic sensors (AKA: transducers) 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. 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, medical ultrasonography, burglar alarms, and non-destructive testing. Systems typically use a transducer which generates sound waves in the ultrasonic range, above 20,000 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.

2.5 The PIC16F873 Microcontroller

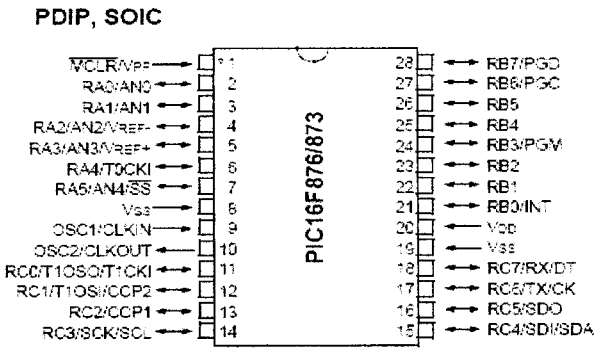

Figure 2.4: PIC 16F873 pin diagram

A microcontroller (or MCU) is a computer-on-a-chip used to control electronic devices. It is a type of microprocessor emphasizing self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor (the kind used in a PC). A typical microcontroller contains all the memory and interfaces needed for a simple application, whereas a general purpose microprocessor requires additional chips to provide these functions. A microcontroller is a single integrated circuit with the following key features:

- central processing unit - ranging from small and simple 8-bit processors to sophisticated 32- or 64-bit processors
- input/output interfaces such as serial ports
- peripherals such as timers and watchdog circuits
- RAM for data storage
- ROM, EEPROM or Flash memory for program storage
- clock generator - oscillator for quartz timing crystal, resonator or RC circuit

PIC16F87X microcontrollers are built on the popular 14 bit PIC16C core and offer significant improvements over earlier cousins. As this 16F873 microcontroller module uses only 28 pin devices. Some features of these devices are highlighted below:

2.5.1 Memory

PIC16F87X microcontrollers carry a large memory array, which can be divided into three types:

- Flash Program Memory
- EEPROM Data Memory
- Data RAM (SRAM)

i. Flash Program Memory

The entire program memory is made up of flash array. Every single byte of flash program memory can be erased and reprogrammed. This can be done either in a conventional PIC programmer such as economical PICSTART units available from Microchip, or can even be done during an application. And all this can be done by a small user code resident in program memory, without requiring any external higher programming voltage.

Reading and writing to program memory through user code is done through a set of special function registers (SFRs). The program memory is not limited to storing code bytes, but can also be used to store 14 bit of coefficient constants. An accidental access to an invalid code byte will result in execution of NOP code, without causing any harm. But unfortunately, it cannot be relied upon and care should be taken to ensure that any coefficient bytes are not accessed as program code bytes. The lower of PIC16F873 has 7168 Bytes (4096x14 Words) of code memory.

ii. EEPROM Data Memory

EEPROM data memory is suitable for multiple erase and writes operation. This is normally suitable for storing coefficient data, which may be programmed from time to time. The EEPROM data memory is not mapped in register file address space, but is mapped differently, and is also accessed through a set of SFRs. PIC16F873 contains 128 Bytes of EEPROM data.

iii. Data RAM (SRAM)

RAM availability in microcontrollers is increasing steadily and PIC16F series is no exception. PIC16F873 contains 192 Bytes of SRAM and the data memory is partitioned into 4 banks of 128 Bytes each. The lower section (00 to 20H) of each of these banks is devoted to special function registers, and the balance is left for Data RAM. Since PIC16F873 only contains 192 Bytes of Data RAM, these are all contained in the first two banks. Only SFRs are located in the upper two banks bank 2 & bank 3.

2.5.2 Peripherals

i. A/D Converter

A/D converter resolution has been improved from standard 8-bit to 10 bit. This is reasonably good, and 16F87X microcontrollers can compete for a place in industrial control. 5 10-bit A/D channels are provided. The conversion rate can be adjusted internally, but for 10 bit results, a conversion time (including sample and hold) of 20 μsec is optimum. Some of the analog input channels can be configured as digital I/O, if all five channels are not needed. It is also possible to use an external precision reference voltage, but is generally overkill for this resolution.

ii. Timers/Counters/PWM

Accurate counting and timing circuits are becoming a necessity for modern industrial control. There are three timers on-board, which can also be configured to operate as counters.

- 8-bit Timer0
- 16 –bit Timer1
- 8-bit Timer2