Non-Intrusive Liquid Level Detection System

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To my beloved father, mother, brothers and sisters

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ABSTRACT

Liquid level measurement is a key aspect for many applications in the processing industry. Liquid handling offers many challenges for measurement and control. Especially when the liquid is corrosive, contaminated or poisonous. In industries, it is very common that the method used for measuring the liquid level is by using the direct contact method. This kind of method required the sensor to have direct contact with the liquid. By using this method the material of the sensor will affected the liquid and the sensor also have high probability to damage by the liquid itself. There are various techniques which can be used for this project. To achieved the objective of this project ultrasonic technology method is used. For this project, ultrasonic transducer is used to measure the liquid level of the tank. Using the ultrasonic sound and the time between the transmitted and received pulse, the distance traveled by the ultrasonic wave can be calculated. Then the distance value will be converted into level and displayed LCD display.

ABSTRAK

Pengukuran paras cecair adalah aspek utama untuk banyak aplikasi dalam industri pemprosesan. Pelbagai cabaran ketika pengendalian cecair dilakukan dalam pengukuran dan kawalan. Terutamanya bila cecair bersifat mengkakis, tercemar atau beracun. Dalam industri, kaedah umum yang biasa digunakan untuk mengukur tahap cecair adalah dengan menggunakan kaedah sentuhan secara langsung. Kaedah ini melibatkan sensor untuk menyentuh cecair. Dengan menggunakan kaedah ini bahan dari sensor akan terkena cecair dan sensor juga mempunyai kebarangkalian tinggi untuk rosak. Ada pelbagai teknik yang boleh digunakan untuk projek ini. Untuk mencapai objektif projek ini, teknologi ultrasonik digunakan. Untuk projek ini, transduser ultrasonik digunakan untuk mengukur tahap cecair di dalam tangki. Dengan menggunakan gelombang ultrasonic, masa diambil ketika menghantar gelombang dan menerima gelombang, serta jarak yang dilalui oleh gelombang ultrasonik boleh dikira. Nilai tahap ketinggian cecair akan dipaparkan skrin LCD.

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, level measurement is one of the most common types of measurement undertaken and is used significantly in many process systems. The most predominant area is the need to determine the amount of liquid in a vessel, such as a tank, in order to control and regulate the process. In the waste water industry for example, level measurement is used in maintaining the levels in chemical tanks. In this type of application, a level measurement device would monitor the level of chemical and the device would send out a signal when the tank is full or reaches a certain set level, shutting down the pump.

Continuous level monitoring method is used, whereby the device measures level on a constant basis and displaying on the LCD or transmitting the actual level of the liquid in a tank as it changes. Knowing the height of a tank allows an operator or user to calculate back how much liquid is present at any given time. This is extremely useful information in managing inventory or in gauging process performance. Example the

method that can be considered for this project is admittance, ultrasonic, magnetic, radar and differential pressure.

Most continuous monitoring systems use a transducer unit to interact with the liquid level being measured. Ultrasonic devices emit electromagnetic energy in order to detect the level of the liquid at that second. A non-contact device, such as Ultrasonic, does not require direct contact with the liquid surface in order to perform properly.

1.2 Problem Statement

The conventional method of measuring liquid level is by using a dipstick or calibrated float. However, this kind of method is not suitable in some situations for example, sometimes a sealed container cannot be opened, or its contents cannot be exposed. In industries, it is very common that the method used for measuring the liquid level is by using the direct contact method. The liquid, especially the corrosive chemical can corrode the sensor and can alter the quality of the liquid in a tank.

Ultrasonic liquid level measurement is often a good solution for situations that require fast, automatic measurement of level in a large number of containers. Ultrasonic is suitable for measuring levels of caustic or reactive fluids in chemical processing applications where the container cannot be opened for safety reasons. Also for checking assembly line fluid levels in a variety of automotive components, such as fuel tanks, transmission assemblies, and engine oil pans, in which a fast and reliable nonintrusive measurement is required.

1.3 Objective

The main objective of this project is to develop an ultrasonic level measuring system for a liquid tank. It is a device that can measure the level of liquid inside the tank using ultrasonic wave and the liquid level can be displayed to the user either through a display panel or meter. This project looks into researches based on the ultrasound technology as non-intrusive sensor. In this project, the study of the transmitting and receiving concept of sound wave, the length of time, the equation of the wave velocity and calculation of the wave length are worked upon and determined. The software codes are also need to be developed for the PIC 16F877A (control the LCD display and calculation level of liquid).

1.4 Scope of Project

The scopes listed to ensure the project is conducted within its intended time frame and scale. It also helps to ensure that the project is heading in the right direction to achieve its objectives listed as follows:

1. study the principle and application of ultrasonic wave.
2. To construct and study the hardware of the circuit until it performs as desired.
3. To develop software codes that can allow the circuit to detect and measure the level of the liquid.

Basically, this project is divided into two main parts:

1. **Hardware design:** The hardware for the ultrasonic level measuring system can be broken down into three functional units, the LCD display, Ultrasonic circuit and the PIC circuit. It consists of the operation of ultrasonic sensor to transmit and detect the sound wave and the operation to control the display and the calculation for measurement.

2. **Software design:** The program for the ultrasonic level measuring system essentially does two things: transmit a pulse and detect when the pulse is received. The program is developed to measure the time that elapsed between the time transmission of the ping and reception of the pong. The display of the measurement is made using LCD displays.

1.5 Project Methodology

This project focus more on study case and the project development base on ultrasonic technology. The project methodology shows that the step by step taken to complete the project. The methodology includes the planning, the development of the design and the management of the project.

CHAPTER 2

BACKGROUND THEORY

This chapter presents the background theory of ultrasonic wave including its characteristics that are useful in order to develop this project. The details of ultrasonic transducer are discussed and followed by explanation on the measurement principles. Several factors that can affect the performance of ultrasound are also included.

2.1 Ultrasonic

Ultrasound is the sound generated above the human hearing range (typically 20 kHz). Ultrasound is cyclic sound pressure with a frequency greater than the upper limit of human hearing. Ultrasound has a much shorter wavelength. It can be reflected off very small surfaces such as defects inside materials. It is this property that makes ultrasound useful for nondestructive testing of materials.

The ultrasonic technology is used in many different fields, typically to penetrate a medium and measure the distance or supply focused energy. The reflection signature can reveal details about the inner structure of the medium.

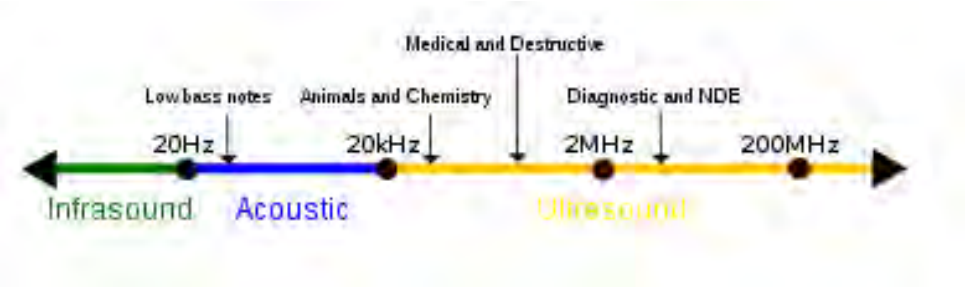

Figure 2.1 Frequency ranges corresponding to ultrasound

2.1.1 Velocity of Ultrasound and Wavelength

The velocity of ultrasound, c in a perfectly elastic material at a given temperature and pressure is constant. The relation between c, f, λ and T is given by Equation (1) and (2):

$$\lambda = \frac{c}{f} \qquad \text{Equation (1)}$$

$$\lambda = cT \qquad \text{Equation (2)}$$

Where λ = Wavelength
c = Material sound velocity
f = frequency
T = Period of time

2.2 The Advantages of Ultrasonic

1. Able to measure and detect distances to moving objects
2. Impervious to target materials, surface and color
3. Solid-state units have virtually unlimited, maintenance-free lifespan
4. Detects small objects over long operating distances
5. Resistant to external disturbances such as vibration, infrared radiation and ambient noise
6. Dust, dirt or high-moisture environments do not affect ultrasonic sensor.

2.3 Principle of Level Measurement

The transducer (ultrasonic sensor) measures the length of time from the transmission to reception of the ultrasonic signal (pulse), reflected from an object that was transmitted from the sensor, thereby it calculates the distance and level between the sensor and the object its distance or level to be measured.

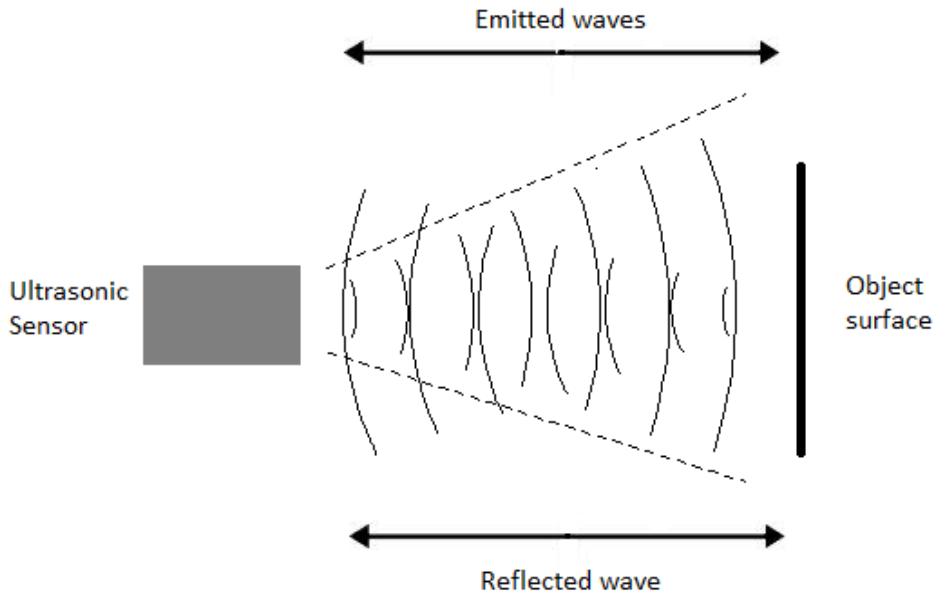

Figure 2.3 Operation of Ultrasonic Sensor

Distance [m] = {Pulse Delay Time x the Velocity of Sound} /2
The velocity of Sound in Air [m/sec] = 331.5 + 0.6 x Temperature [℃]

There are many limiting factors to consider. Sound diverges very rapidly, so transducers are producing as small a beam as possible required. Some applications require a wide beam. A narrow beam improves the range and reduces background interference. The wider the beam, the greater the possible angle between the transducer and the surface. When the angle is too great the reflected beam misses the transducer

because some surfaces may produce scattered diffuse reflections, this will make the beam much weaker and not suitable for distance measuring purposes.

2.3.1 Temperature

The speed of sound varies with temperature: as air gets warmer, sound travels faster. Hence ultrasonic systems must incorporate a thermometer to estimate the current speed of sound. While the ambient air temperature can be measured, other warming effects, such as convection and turbulence, can cause errors in the calculated distance. Temperature also can affect the sound velocity in the atmosphere. The sound velocity in the atmosphere can reach 331.45 m/s when the temperature is 0°c.

2.3.2 Humidity

Humidity can influence attenuation of sound in air, which can affect the maximum range of an ultrasonic device. Attenuation is also related to the frequency of the emitted sound: higher frequencies improve the sampling resolution, but it reduces the maximum measurement distance.

2.4 Basic Applications of Ultrasonic Transducer

2.4.1 Solid Level

Dry material level in a container can be measured if the materials have enough ultrasonic echoes for reliable detection. Certain materials absorb sound wave, there is no way ultrasonic can be used for this kind of material. The incline of the material must also be such that a proper sound echo is obtained at those times when the level measurement is required. Figure 2.4.1 shows the application in measuring solid level.

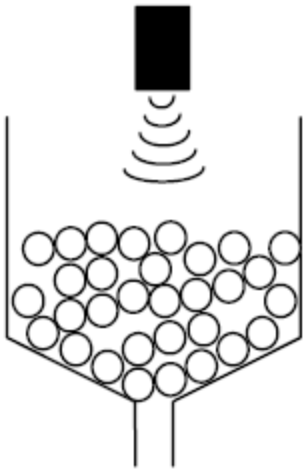

Figure 2.4.1 Application in measuring solid level

2.4.2 Object Dimension

Ultrasonic sensor also can measure dimension of an object. The height of an object can be measured from the floor until the top of the object. Width of an object can be determined by measuring the object from 2 sides. Figure 2.4.2 shows the application of ultrasonic in measuring object dimension.

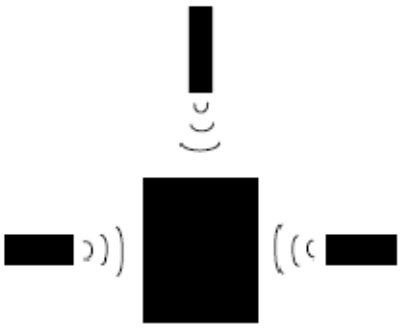

Figure 2.4.2 Application in measuring object dimension

2.4.3 Height Difference

Difference height of the object in the same line can be measure by ultrasonic. It is very useful to apply especially on a conveyor belt by discriminate out-of-dimension objects. Figure 2.4.3 shows the application in detecting the height difference.

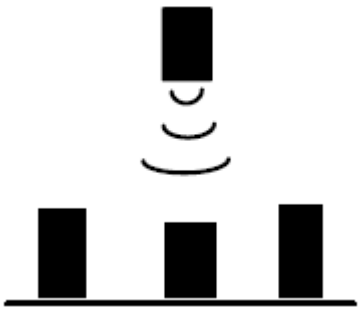

Figure 2.4.3 Application of ultrasonic in height difference

2.5 Literature Review

2.5.1 Operating Principle

Ultrasonic Transmitter sends an electrical signal to the transducer piezoelectric crystal, which causes the crystal to vibrate and emit an ultrasonic pulse. The sound pulse is emitted toward the liquid surface. Then the signal reflected as an echo, back to the transducer. When the return signal echo is received, the electronic circuit converts the time interval into a distance. The relationship can be shown as below.

$$D = \frac{Vt}{2}$$

D = Distance

t = time required

V = velocity of sound