DESIGN OF ULTRASONIC DETECTION SYSTEM FOR RESTRICTED AREAS

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For my beloved father and mother
Roslan Bin Abd. Rashid and Rohani Binti Hassan
For all supported and understanding.

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

In the name of Allah, The Beneficent, The Merciful

A great thankful to the God, ALLAH S.W.T for the giveness so that I had finished overall ‘Projek Sarjana Muda 1’ and ‘Projek Sarjana Muda 2’ reports for this semester. This project was accomplished include the hardware of ‘Ultrasonic Detection System’ as planned.

A lot of thank for my project supervisor Prof. Madya Dr. Musse Mohamud Ahmed. Contribution that he had gave helping me in working for this project. His brilliant ideas and lesson would be so hard for me to forget. For my fellow friends, thanks a lot for their contribution.

Last but not least, I would like to honor my lovely parents, for their supported and appreciated advice through out my project duration.

Thank you to all.

ABSTRACT

This is a very interesting project with many practical applications in security and alarm systems for homes, shops and cars. It consists of a set of ultrasonic receiver and transmitter which operate at the same frequency. When something moves in the area covered by the circuit the circuit's fine balance is disturbed and the alarm is triggered. The circuit is very sensitive and can be adjusted to reset itself automatically or to stay triggered till it is reset manually after an alarm.

Ultrasonic waves are produced electrically using an electroacoustic transducer (piezoelectric effect), which converts electrical energy supplied to it in the form of mechanical vibrations thanks to piezoelectricity or magnetostriction phenomena. The advantage of ultrasonic sensors is that they can operate over long distances (up to 10 m) and, above all, that they can detect any object, which reflects sound, regardless of its shape or color.

In this project of ultrasonic detection system, the hardware has been designed and from this project, the characteristic of the transducer, the operation of ultrasonic sensor and lot more can be studied and understood. This project 'Design of Ultrasonic Detection System for Restricted Area' is an important application nowadays and always has efforts to improve and upgrade in the future.

ABSTRAK

Ini merupakan suatu projek yang sangat menarik dan banyak mmpraktikkan aplikasi di dalam sistem keselamatan dan sistem penggera untuk rumah, kedai dan kereta. Projek ini melibatkan penggunaan satu set penerima dan penghantar ultrasonik yang beroperasi pada frekuensi yang sama. Apabila sesuatu pergerakan berlaku di dalam kawasan litar, keseimbangan litar akan terganggu dan penggera akan beroperasi. Litar ini terlalu sensitif dan boleh dikawal untuk diset semula secara automatik ataupun dengan membiarkan litar dalam keadan tersebut sehingga ia diset semula secara manual selepas penggera berbunyi.

Gelombang ultrasonik dihasilkan dengan menggunakan tranduser (kesan piezoelectric) yang mengubah tenaga elektrik yang dibekalkan kepadanya dalam bentuk getaran mekanikal sejajar dengan ‘piezoelectricity’ atau fenomena ‘magnetostriction’. Antara kelebihan menggunakan pengesan ultrasonik ialah pengesan ini dapat beroperasi pada jarak yang jauh (sejauh 10 m) dan pada jarak ini, ia dapat mengesan sebarang objek, yang membalikkan bunyi, tanpa mengira warna atau bentuk.

Di dalam projek sistem pengesan ultrasonik ini, alat ini telah dihasilkan dan daripada projek ini, ciri tranduser, operasi yang dijalankan dalam pengesan ultrasonik dan banyak lagi boleh dipelajari dan difahami. Projek ‘Design of Ultrasonic Detection System for Restricted Area’ ini merupakan aplikasi yang penting dunia pada hari ini dan usaha untuk membaiki dan menambahbaik projek ini sentiasa berkembang pada masa akan datang.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Prior to World War II, sonar, the technique of sending sound waves through water and observing the returning echoes to characterize submerged objects, inspired early ultrasound investigators to explore ways to apply the concept to medical diagnosis. In 1929 and 1935, Sokolov studied the use of ultrasonic waves in detecting metal objects. Mulhauser, in 1931, obtained a patent for using ultrasonic waves, using two transducers to detect flaws in solids. Firestone (1940) and Simons (1945) developed pulsed ultrasonic testing using a pulse-echo technique. [2]

Nowadays, ultrasonic sensors have lot of application in our daily life. This technology can be used for measuring such as 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.

This project focuses on getting the design of ultrasonic detection system for restricted area where the design and the hardware for this project are required to accomplish this project. This project suggested by Prof. Madya Dr. Musse Mohamud Ahmed, engineering lecturer in UTEM. This project is design with a pair of transducer and several connections of electronic components to complete its circuit design. The hardware that produce, Ultrasonic Detection

System for Restricted Areas, useful for alarm system that are commonly used by vehicles to protect themselves from nearby objects come from the back.

It consists of a set of ultrasonic receiver and transmitter which operate at the same frequency. If there is some movement in the area covered by the ultrasonic emission the signal that is reflected back to the receiver becomes distorted and the circuit is thrown out of balance. The output of the IC2 in uses changes abruptly and the Schmitt trigger circuit which is built around the remaining two gates in IC3 is triggered. For this project, when something moves in the area covered by the circuit, the circuit fine balance is disturbed and the alarm is triggered. The circuit is very sensitive and can be adjusted to reset itself automatically or to stay triggered till it is reset manually after an alarm. Specially, the circuit works from 9-12 VDC and can be used with batteries or a power supply.

1.2 Problem Statement

Nowadays, houses, cars and shops are very important properties posses by humans. Many incidents can happen which causes by less security to protect themselves. Also the incoming of the intruders from the other country at the border. We can conclude that there are no such things of security which can handle these problems before. To solve these, the development of high quality sensor is required to be developed.

1.3 Project Objectives

The following objectives are the main reason why this ultrasonic detection system for restricted is require to be developed:

1. To build a system that can detect intruder at houses or any other building structures. (especially at the main doors or gates)
2. To build a system that can avoid cars, jeeps and lorries from crushed at the backside on reverse situation.
3. Develop a system which will detect any unwanted object to come near to the security zone.
4. Uses radar system for military purposes.

1.4 Scope of Project

Final of this project, student would have benefit from it. These involve the student to apply the:

1. Use of the application of transducer to build the project.

2. Get the knowledge from the design of ultrasonic detection circuit

3. Make the ultrasonic detection circuit functional and operational.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This project consists of some electronic devices that work as main parts of this project as a sensor device such as ultrasonic receiver and transmitter to generate this design appropriately. This project also consists of the other basic electronic components like capacitor, resistor, diode, transistor, and trimmer to build this project. Integrated Circuit (IC) and Operational Amplifier (Op-Amp) also were used in the design for give more safety and reduce the parts that were used in circuit design. All the information and project theory for this project will be described in this section.

2.2 Operation of Circuit

This project 'Design of Ultrasonic Detection System for Restricted Areas' consists of a set of ultrasonic receiver and transmitter which operate at the same frequency. When something moves in the area covered by the circuit, the circuit's fine balance is disturbed and the alarm is triggered.

The circuit is very sensitive and can be adjusted to reset itself automatically or to stay triggered till it is reset manually after an alarm. As it has already been stated the circuit consists of an ultrasonic transmitter and a receiver both of which work at the same frequency. They use ultrasonic piezoelectric transducers as output and input devices respectively and their frequency of operation is determined by the particular devices in use.

The transmitter is built around two NAND gates of the four found in IC3 which are used here wired as inverters and in the particular circuit they form a multivibrator the output of which drives the transducer. The trimmer P2 adjusts the output frequency of the transmitter and for greater efficiency it should be made the same as the frequency of resonance of the transducers in use. The receiver similarly uses a transducer to receive the signals that are reflected back to it the output of which is amplified by the transistor TR3, and IC1 which is a 741 op-amp. The output of IC1 is taken to the non inverting input of IC2 the amplification factor of which is adjusted by means of P1. The circuit is adjusted in such a way as to stay in balance as long the same as the output frequency of the transmitter. If there is some movement in the area covered by the ultrasonic emission the signal that is reflected back to the receiver becomes distorted and the circuit is thrown out of balance. The output of IC2 changes abruptly and the Schmitt trigger circuit which is built around the remaining two gates in IC3 is triggered. This drives the output transistors TR1, 2 which in turn give a signal to the alarm system or if there is a relay connected to the circuit, in series with the collector of TR1, it becomes activated. The circuit works from 9-12 VDC and can be used with batteries or a power supply.

2.3 Fundamentals of using ultrasonic sensors

An ultrasonic sensor houses a transducer that emits high-frequency, inaudible acoustic waves in one direction when the transducer element vibrates. If the waves strike and bounce off an object, the transducer receives the echoed signal. The sensor then determines its distance from the object based on the length of time between the initial sound burst and the echo's return. Typically, a sensor has a near and a far limit that are set with push-button programming. The sensor determines whether an object is present within those limits.

For example, when an ultrasonic sensor mounted above a tank of liquid or bin of pellets emits waves into the container, the length of time it takes for the echo to return indicates whether the container is full, empty, or partially filled.

Some ultrasonic sensors use a separate emitter and receiver transducer. These opposed-mode ultrasonic sensors work well in applications that require edge detection, faster response time or that have wet environments.

Ultrasonic sensors should be a first choice for detecting clear objects, liquids, dense materials of any surface type (rough, smooth, shiny), and irregular shaped objects. Ultrasonic sensors are not suitable outdoors, in extremely hot environments, or in pressure tanks nor can they detect foam objects. [3]

2.4 The Ultrasonic Transducer

Sound that is generated above the level of human hearing range is called ultrasound. Although ultrasound typically starts at 20 KHz, most ultrasonic transducers start at 200 KHz. Ultrasound, which is similar in nature to audible sound, has far shorter wavelengths and is far more suitable to detect small flaws. These shorter wavelengths are what make ultrasound and ultrasonic transducers extremely useful for nondestructive testing and measurement of materials.

An ultrasonic transducer itself is a device that is capable of generating and receiving ultrasonic vibrations. An ultrasonic transducer is made up of an active element, a backing, and wearplate. The active element is a piezoelectric or single crystal material which converts electrical energy to ultrasonic energy. It will also then receives back ultrasonic energy and converts it to electrical energy. The electrical energy pulse is generated from an instrument such as a flaw detector.

The backing is most commonly a highly attenuative and very dense material and is used to control the vibration of the transducer crystal by absorbing the energy that radiates from the back face of the piezoelectric element. When the acoustic impedance of the backing material matches that of the piezoelectric crystal, the result is a highly damped transducer with excellent resolution. By varying the backing material in order to vary the difference in impedance between the backing and the piezoelectric crystal, a transducer will suffer somewhat and resolution may be much higher in signal amplitude or sensitivity.

The main purpose of the wear plate is simply to protect the piezoelectric transducer element from the environment. Wear plates are selected to generally protect against wear and corrosion. In an immersion-type transducer, the wear plate also serves as an acoustic transformer between the piezoelectric transducer element and water, wedge or delay line.

2.5 Transmitter Impedance Characteristics

Ultrasonic transmitter impedance characteristics vary with operating frequency and temperature in a complex manner that is different for each construction. In general, for frequencies approximately 0.1 octave on either side of the resonant frequency, the transmitter looks like a capacitor. The current through the transmitter will lead the voltage developed across the transmitter by 90 degrees.

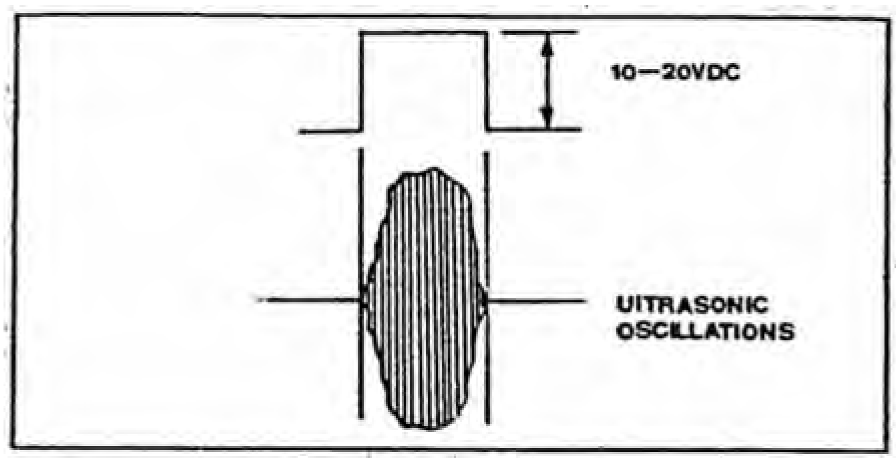

Figure 2.1 Ultrasonic Oscillations

As the resonant frequency is approached, the voltage drop across the transmitter will decrease to a minimum at the resonant frequency (minimum series impedance) and the current will increase proportionally. The phase lead to this current relative to the voltage will decrease to zero near the resonant frequency and the transmitter will then appear to be a pure resistance. As the frequency is increased above the resonant point, the current may now lag the voltage by an increasing amount (maximum of 90 degrees) as the voltage across the transmitter climbs to a peak which is defined as the anti-resonant point. During this transition, the transmitter appears to have an inductive characteristic.

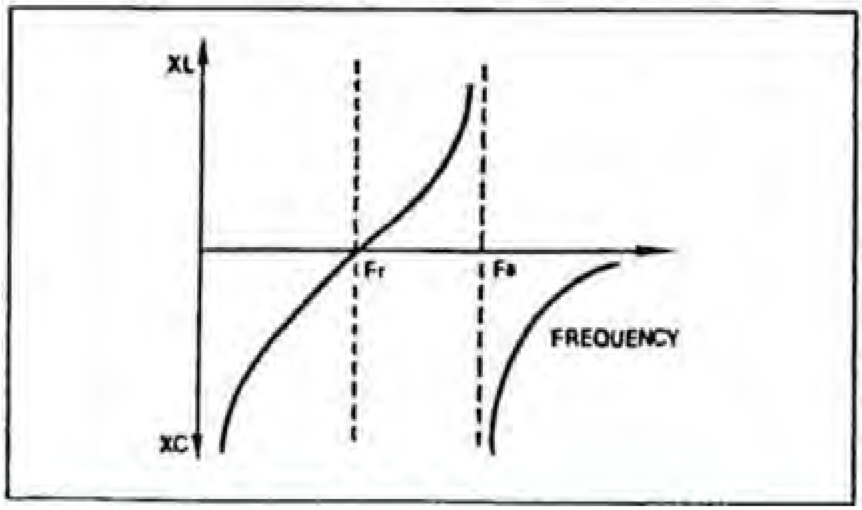

Figure 2.2 Transmitter Characteristic

Increasing temperature will lower the resonant frequency and thus the point at which the phase changes will occur. The rate and magnitude of phase change is more stable than the resonant frequency. The test circuit shown in Figure 2.3 may be used to measure the resonant, anti-resonant, and impedance characteristics of ultrasonic transducers. Adjust frequency to obtain maximum EOUT. Switch in VR and adjust to obtain the same output. VR now equals the minimum series impedance.

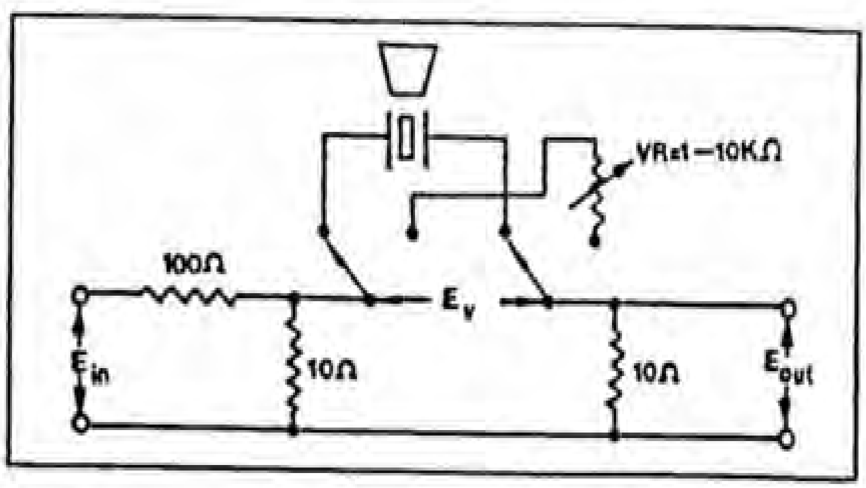

Figure 2.3 Ultrasonic Transducer Test Circuit

Adjust frequency to obtain minimum EOUT. Switch in VR and adjust to obtain same output. VR now equals the maximum series impedance at the anti-resonant frequency. The impedance characteristics can be determine by measure phase between voltage EU and EOUT. [4]

2.6 The Sound Field

The sound field of a transducer has two distinct zones. These zones are called the near field, which is the region directly in front of the transducer, and the far field which is the area beyond "N" where the sound field pressure gradually drops to zero. Because of variations of the near field, it may be very difficult to accurately measure and evaluate flaws.

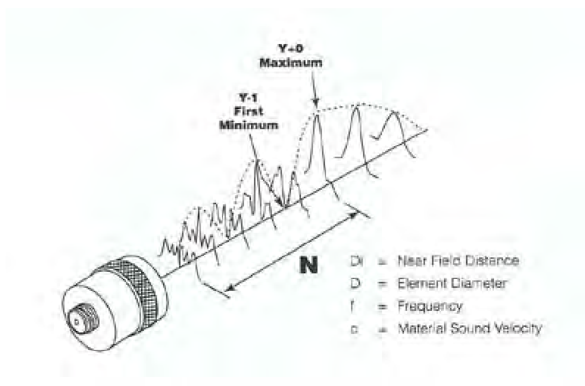

Figure 2.4 Transducer Distinct Zone

The near field distance is a function of the transducer frequency, element diameter, and the sound velocity of the test material as shown in the following equation:

$$N = D^2/4c \tag{2.1}$$

2.7 The Sound Beam

There are several sound field parameters that are very useful in describing the characteristics of an ultrasonic transducer. Knowledge of the focal length, beam width and focal zone may be necessary in order to determine whether a particular transducer is appropriate for an application.

One reason that focusing increases the sensitivity of a transducer is that it results in a decrease in the sound beam diameter. This means that a small flaw will reflect a greater portion of the transmitted sound energy. The -6dB pulse-echo beam diameter at the focus can be calculated with the following equation:

$$BD_{(-6dB)} = 1.028\ Fc/fD \quad (2.2)$$

BD = Beam Diameter F = Focal Length

c = Material Sound Velocity f = Frequency

The starting and ending points of the focal zone are located where the on-axis pulse-echo signal amplitude drops to -6dB of the amplitude of the focal point. The length of the focal zone can be calculated with the following equation:

$$Fz = NS^2_F\ [2/(1 + .5S_F)] \quad (2.3)$$

Fz = Focal Zone N = Near Field

S_F = Normalized Focal Length

All transducers have beam spread and the consideration of the beam spread is important when inspecting flaws that may be close to certain geometric features of the material to be tested. These features include side walls and corners which may cause spurious echoes that could be mistaken for flaws or defects.

For flat transducers the -6dB pulse-echo beam spread angle is well defined and is given by equation:

$$\text{Sin}\ (\alpha/2) = .514c/fD \quad (2.4)$$

It can be seen from this equation that beam spread in a transducer can be reduced by selecting a transducer with a higher frequency or a larger diameter, or both.

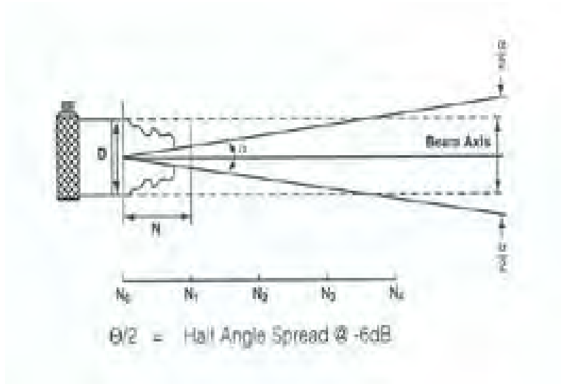

Figure 2.5 Distinct Zone

2.8 Transducer Types

1. Straight Beam Contact Transducers are the most common and frequently used to introduce longitudinal waves into a material. Also, by using special elements, normal incidence shears wave or a combination of longitudinal/shear wave transducers can be made. This type of transducer is used in direct contact with the test material and therefore requires a highly durable wear plate.
2. Angle Beam Transducers utilize the basic principle of refraction and mode conversion to produce refracted shear or longitudinal waves in the test material. The angle of incidence required to produce the desired refracted wave is calculated from Snell's Law.The following formula may be used to calculate the Wedge angle (Q1) required to generate the desired mode and refracted angle (Q2) in the material under test.

$$\text{Sin } Ø_1/\text{Sin } Ø_2 = V_1/V_2 \qquad (2.5)$$

$Ø_1$ = Wedge Angle

$Ø_2$ = angle of refracted wave in test material

V_1 = Longitudinal velocity of wedge material

V_2 = Velocity of material being inspected for the desired mode

3. Dual Element Transducers use separate elements to transmit and receive ultrasound signals. The elements are typically cut at an angle and mounted on delay lines. This helps to improve near surface resolution and the cross-beam design also helps to create a focus which makes dual element transducers more sensitive to echoes from irregular defects caused from corrosion and pitting.
4. Immersion Transducers have several advantages over contact-type transducers. First, their uniform coupling reduces variations in sensitivity. Second, immersion transducers offer increased speed from the ability to perform automated scanning. Third, the focusing of immersion transducers increases the sensitivity to small defects. Immersion transducers are available in unfocused, spherically focused, and cylindrically focused configurations. An unfocused immersion transducer is used for general applications in the measurement of thick materials. A spherically focused transducer will improve the sensitivity to small flaws and defects. A cylindrically focused transducer is typically used in the measurement of tubing raw stock. The range of focal lengths for a spherical or cylindrical transducer is limited to the transducer's near field and is generally a maximum of 0.8N. [5]

2.9 Ultrasound transducers for measuring distance

Ultrasound interacts with hard body and part of incoming wave energy is reflected back, in other words – it is back scattered. So direct wave towards object is back scattered widely – up to 180°. If object is moving – received frequency differs because of Doppler effect. Lets say simple example – parking sonar. Distance to object can be calculated very simply by formula:

$$L=v\cdot t\cdot\cos(\alpha)/2 \qquad (2.6)$$

Where t-time period between transmitted and received signals; v–ultrasound speed; α–signal angle to object. If signal is perpendicular to object then cos(α)=1.