PPU College of Engineering and Technology

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Electrical and Computer Engineering Department

Biomedical Engineering Program

Bachelor Thesis

Graduation Project

Design and Implementation of an Air Bubble Detector using an Ultrasound Principle with Audible Alarm

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جامعة بوليتكنك فلسطين
الخليل-فلسطين
كلية الهندسة والتكنولوجيا
دائرة الهندسة الكهربائية والحاسوب

اسم المشروع

Design and Implementation of an Air Bubble Detector using an Ultrasound Principle with Audible Alarm

اسماء الطلبة

حنين شلالدة   رنا ادعيس

بناء على نظام كلية الهندسة والتكنولوجيا واشراف ومتابعة المشرف المباشر على المشروع وموافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع الى دائرة الهندسة الكهربائية والحاسوب، وذلك للوفاء بمتطلبات درجة البكالوريوس في الهندسة تخصص هندسة الاجهزة الطبية.

توقيع المشرف

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توقيع اللجنة الممتحنة

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Abstract

The idea of our project is to design an Air Bubble Detector by using the characteristics of the ultrasound sensor dependently on the transmitting and receiving signal which is passing through many stages that will give the amplitude of the signal resulting from the blood with air and compare it with the amplitude of signal, that result from the blood without air bubble and we use an Audible alarm to indicate air bubble.

ملخص المشروع

إن مشروعنا هذا يطرح الحل لمشكلة تشكل فقاعات الهواء في الدم وذلك من خلال قيامنا بتصميم جهاز كاشف فقاعات الهواء بالاعتماد على خصائص الموجة لمجس الأمواج فوق السمعية ،ونحن بهذا نقوم بإفادة الجميع بدءاً بطلبة تخصص الأجهزة الطبية وذلك من خلال فتح المجال لهم للتطوير عليه وأيضا للمرضى الذين قد يواجهون هذه المشكلة وذلك بالتخفيف من مخاوفهم ومساعدة الأطباء في عملهم.

الاهداء

بسم الله الرحمن الرحيم

قاسينا وسهرنا وتعبنا وها نحن اليوم وبحمد الله نطوي سهر الليالي وتعب السنين التي مضت ونقدم بين طيات هذا الكتاب خلاصة مشوارنا ...

اليك حبيبي وسيدي يا منارة العلم وهداية البشرية يا من انقذتني برسالتك من ظلمات الجهل وكنت النجم الذي اهتدي بها اذا ما اسود ليلي اليك يا سيدي ونبي محمد صل الله عليه وسلم ...

الى أطيب قلب وأجمل ابتسامة وأعذب حديث اليك امي يا من كنت شريكتي في سهري وتعبي في حزني وفرحي أدامك الله تاجا فوق رؤوسنا يا من كنتي لي أما واختا وصديقة...

اليك يا من ضحيت بعمرك من اجلي وأثرت راحتي على راحتك وأحرقت شمعت أيامك وشبابك من أجل ان تضعني على أول الطريق اليك ابي حفظك الله منكل شر وأطال عمرك ...

اليكم يا من رويتم بدمائكم الطاهرة أرض بلادي يا من ضحيتم بأرواحكم من أجلنا من أجل ضمان بقاءنا على هذه الارض رحمك الله وأحلكم الفردوس الأعلى ...

اليكم أسرانا البواسل أيها الصامدون خلف قضبان الزنازين يامن حولتم بمعركتكم معركة الامعاء الخاوية ذكرى النكبة الى ذكرى انتصار لشعبنا وأثبتم للعالم أن لا جوع ولا ظلمة السجن وظلم السجان يمكن أن يكسر ارادة هذا الشعب ...

الى من حبهم سكن في أعماق قلبي الذين أدعوا لهم بالسر والعلن أن يحفظهم الله من كل شر وأن يبقيهم نورا لدربي وسندا لي اليكم اخوتي واخواتي ...

اليكم يا من وهبتكم لي الحياة وكنت سندا لي على طول الطريق يا من كنتم سببا في زرع الأبتسامة على وجهي حتى في أصعب الظروف ....الأصدقاء والأحباب ...

اليهم جميعا أهدي هذا العمل ...

والله الموفق

حنين شلالدة

رنا ادعيس

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Introduction

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Chapter One

Introduction

[1.1] Overview

In medical field, during the treatment of patients, there is a need to re-circulate the blood of patient outside the body and return it back again. These operations are considered as serious operations, because of some problems may occurred during it. The most and main problem is known as air bubble in blood.

An electronic device is used generally to:
Detect anomalous bubbles in high precision chemical processes, enable precise measurement of fluid flow, Protect patients from embolisms due to air which introduced through IV lines into the blood stream and determine fluid flow rate.

There are two methods to detect air bubble: invasive and non invasive but in this project we concern about detecting air bubbles that may go through patient blood, so we will talk about non-invasive method.

In non invasive method there are three sensors that used to detect air bubble Optical, Capacitance and Ultrasonic sensors.

[1.2] Project Importance

The importance of the project comes from its wide benefits for patients that need to circulate the blood outside the body, and help doctors in their job by reducing their concerns a bout the dangers that will be around the patients .

[1.3] Literature Review

We use some papers that contain important information about our project:

1. Air Bubble Sensor with Simplified Mounting of Piezo Element.
2. Reliability Analysis of Moog Ultrasonic Air Bubble Detector
3. Ultrasonic Transmitter Particularly for an Air Bubble Detector**.**

[1.4]Project Objectives

The main objectives of the project are:

1-To study the physiology of blood and the problems that face it when it is treated.

2- Design an Air Bubble Detector by using ultrasonic sensor to detect the air bubbles in the blood in the tube.

3- Using a Microcontroller and Loudspeaker to give an alarm we will get the main object which is detecting the air bubbles.

[1.5] Project Scheduling

Table [1.1]: Project Scheduling

Task Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Project preparation			■	■												
Data collection				■	■	■										
Analysis project						■	■	■	■							
Conceptual design								■	■	■	■	■				
Studding Project											■	■	■	■		
Documentation							■	■		■	■		■	■	■	

[1.6] Economical Study

This section lists the overall cost of the component that is required in implementation the system.

There are many electronic chips and electrical equipments have to be provided as shown in table below:

Table [1.2]: Hardware Cost

Component	Cost
Resistor and capacitor and IC's	70$
Net and printing paper	50$
Sensor	100$

The total cost of the project is 220$.

[1.7] Report Contents

This report is divided into seven chapters; these chapters are described as follow:

Chapter One: **(Introduction)**

This chapter presents overview, literature review, project objective, and importance of the project, project scheduling, and economical study.

Chapter Two: (Physiology)

This chapter describes the human blood, its function and gives the definition of air bubble embolism including the reasons that cause it; and the danger of air bubble on the patient life.

Chapter Three :(Methods of air Bubble Detections)

This chapter describes the difference between the three methods which are used to detect the air bubble and these methods are optical, capacitive, ultrasonic method.

Chapter Four: (Electrical Design)

This chapter describes the block diagram; explain every stage in the block and the importance of each stage in our project.

Chapter Five: (Software)

This chapter includes the software of the microcontroller.

Chapter Six: (System Implementation)

This chapter includes the testing of our design, experimental result, and project safety.

Chapter Seven: (Conclusion)

This chapter includes conclusion, recommendation and future work.

2

Physiology of Human Blood

Chapter Two
Physiology of Human Blood

[2.1] Introduction

In medical field, during the treatment of patient there is a need to either giving the patient some medical liquids or re-circulate his blood outside the body and return it back again. These two operations are considered as serious operations, because of some problems may occurred during them. The most and main problem is known as air embolization to the blood stream.

[2.2] Air Embolism:

Embolism occurs when a solid, semi solid or gaseous substances traveling in the bloodstream obstructs the blood flow the substances are called an embolus.

Air bubble can penetrate into human body by: small amount of air often get into the blood circulation accidentally during surgery and other medical procedures for example a bubble entering an intravenous fluid line also by injection of drug through needle. A delivered of an air bubble into the circulation through an intravenous (IV) and end up blocking a vessel can cause air embolism.

Air embolism can occur whenever a blood vessel is open and a pressure gradient exists favoring entry of gas. Because the pressure in most arteries and veins is greater than atmospheric pressure, an air embolus does not always happen when a blood vessel is injured. In the veins above the heart, the pressure is less than atmospheric and an injury may let air in. This is one reason why surgeons must be particularly careful when they are operating on the brain, and why the head of the bed is tilted down when inserting or removing a central venous catheter from the jugular or subclavian veins. If somehow air could enter the system, the air will form an "air lock" within the system.

Quite in the same manner this air lock blocks the flow of blood through the arteries and veins, thus bringing the circulation to a halt. Air could be made to enter the circulation either through the arteries or through the veins. When such an injection is given, the air bubbles start traveling toward the right atrium. From right atrium they keep traveling onwards till they come to the lung which There are the capillaries that too narrow to allow the big bubbles to pass.

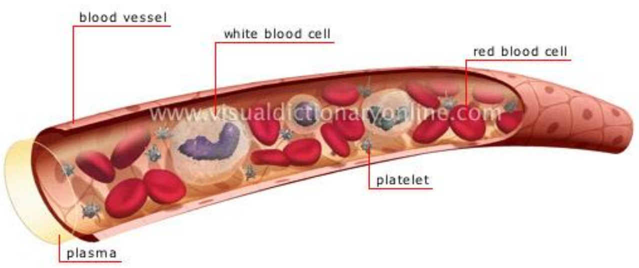
The result is that these bubbles get entangled in the blood vessels of the lung. The whole blood traffic stops and the person die very quickly. In fact his/her blood cannot be purified by the lungs, because traffic of blood towards the lungs has been stopped. The body cannot imagine that such a sinister thing has happened. It "thinks" that the blood is not getting purified because of lack of air.

Large amount of air can cause air embolism in any part of the body, blocking of blood flow. Embolism in the brain can cause sever memory loss and even death. Air trapped in the heart can also cause death or heart damage.

[2.3] Blood:

Is the fluid that is pumped through the body by the heart and contains plasma, blood cells, and platelets "blood carries oxygen and nutrients to the tissues and carries away waste products.

2.3.1 The Blood Consist of:



Figure[2.1]: blood component [1]

1. The Plasma

is relatively clear, yellow tinted water (92+%), sugar, fat, protein and salt solution which carries the red cells, white cells, and platelets. Normally, 55% of our blood's volume is made up of plasma.

2. The Cells of Bloods

1-Red blood Cells (erythrocytes).
2-White blood Cells (leukocytes).
3- Platelets (Thrombocytes).

2.3.2 Function of Blood:

1-Transport

The dissolved gases waste product of metabolism (urea, water), Nutrients, Blood cells and plasma proteins (Anti-bodies& Blood Clotting).

2-Maitain body temperature

The blood regulates the pH and temperature of the human body. When the body needs to cool down the blood flow near the surface of the skin increases and the heat is released from the blood. If the body temperature has to be increased the blood flow at the surface of the skin is decreased and blood is held closer to the body core, allowing necessary heat to be retained.

3-Controls PH

Blood contains buffers that keep the pH of the body between 7.35 and 7.45.

4-Removes Toxins from the Body

Kidney filters all the blood in the body 36 times in 24 hours and so toxins removed from the blood by the kidneys and leave the body in the urine.

5-Regulation of Body Fluid Electrolytes

The excess salt is removed from the body in the form of urine.

[2.4] The Danger of Air Bubble on The Patients

Many studies have shown that rapid infusion of air bubbles may be fatal. They conclude that the entry of air into the venous or arterial system is a risk in virtually all areas of clinical care. Venous emboli may lead to cardiovascular collapse or to paradoxical arterial emboli. Arterial emboli may occlude end arteries throughout the body and may cause serious diseases or death if they occlude cardiac or cerebral vessels.

Irrespective of the mechanism responsible for the embolism, rapid aggressive treatment is essential to preserve life and functions the clinical out come of air embolism depends on the size of the bubbles, location of organ or tissue, general status, comorbidity of the patient, plus many known and unknown factors.

Air bubbles in the bloodstream cause stroke, memory loss and other undesirable effects on the patient. Scientific evidence from human is limited; nevertheless, it supports most of the laboratory findings.

The danger is different from small to big size of air bubble which means each one has its own danger. First ,Big air bubbles have an effect on the heart because it fills the right atrium causing an air lock which is causing an obstruction of the right ventricular outflow tract and decreasing a venous return , decreasing in cardiac output by a compressive of air bubble on the heart and stop the pumping of blood.

Second, Small air bubble can be absorbed by plasma and hemoglobin and it can block capillaries in vital organ, it causes a pain and inflammation to neurological damage and paralysis and it also impedes blood flow.

In general, air bubble or air embolisms both of them have the same danger on patient's lives.

3

Method of air bubble detection

Chapter Three

Method of air bubble detection

[3.1]Introduction

Air bubble detector is an electronic device used generally to detect anomalous bubbles in high precision chemical processes, enable precise measurement of fluid flow, protect patients from embolisms due to air which is introduced through IV lines into the blood stream and determine fluid flow rate.

The researchers and clinicians have found that the air bubble can be detected by using three non invasive methods.

The methods are:

1. Optical method.
2. Capacitive method.
3. Ultrasonic method.

[3.2] How to select the sensor

When we select the sensor we must know the following points:

1. Easy of integration into design or existing system.
2. Type of fluid.
3. Type of tubing or pipe used to transport fluid.
4. Required precision.

5. The cost.

[3.3] Types of sensor

[3.3.1] Optical sensor

[3.3.1.1] Optical Method to Detect Air Bubble

It is one of the techniques which are using optical sensor, a device that converts light rays into electronic signals. Usually, the optical sensor is part of a larger system integrating a measuring device of light and the sensor itself. Using the infrared LED and a phototransistor to detect the magnitude of the light transmitted through the liquid that fill the tube. Basic principle operation of the system is based on the transmission of infusion frequency from the transmitter which is driven by an appropriate circuit.

The signal from infrared LED is transmitted through the line and received by the receiver (phototransistor). Typically, the signal obtained from a phototransistor provides a voltage or a current which is proportional to the measured light intensity.
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The transmission of light between the infrared LED and phototransistor can relate with the Beers law. In optics, the Beers law relates the absorption of light to the properties of the material through which the light is traveling.

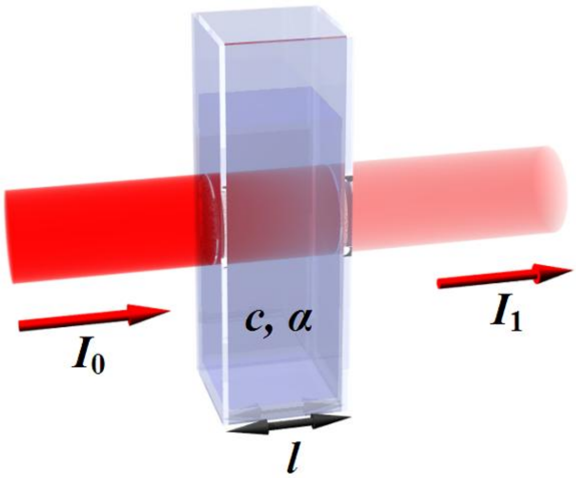


Figure [3.1]: Beers Law [2]

Beers Law: The Beer-Lambert law (or Beer's law) is the linear relationship between absorbance and concentration of an absorbing species. The general Beer-Lambert law is usually written as:

A = a(lambda) * b * c

Where A is the measured absorbance, a(lambda) is a wavelength-dependent absorptivity coefficient, b is the path length, and c is the analyte concentration.

Where I is the light intensity after it passes through the sample and I_o is the initial light intensity. The relation between A and T is:

$A = -\log T = -\log (I / I_o).$ **(1)**

T is transmittance $T = I / I_o$.

[3.3.1.2] Infrared LED

In physics, the term light often comprises the adjacent radiation regions of infrared (at lower frequencies) and ultraviolet (at higher) not visible to the human eye. Light or visible light is the portion of electromagnetic radiation that is visible to the human eye, responsible for the sense of sight.

Visible light has a wavelength in a range from about 380 or 400 nanometers to about 760 or 780 nanometers with a frequency range of about 405THZ to 790THZ. Since light is one form of energy, it is possible to measure the output of light source.

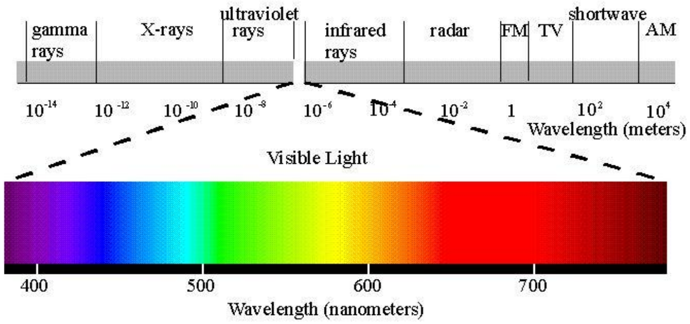


Figure [3.2] Electromagnetic spectrum with light highlight[3]

There is a width selection of light source which is available for optical sensor applications such as:

1. Incandescent lamps

2. Discharge lamp

3. Light emitting diodes (LED)

4. Laser

LEDs present many advantage over incandescent light source including lower energy consumption, longer lifetime, improved robustness, smaller size, faster switching and greater durability and reliability.

Conventional LEDs are made from a variety of inorganic semiconductor materials, colors with wavelength range, voltage drop and material. LEDs are available that emit infrared, red, orange, yellow, green, and blue light. Infrared light is not visible to the naked eye.

[3.3.1.3] Phototransistor

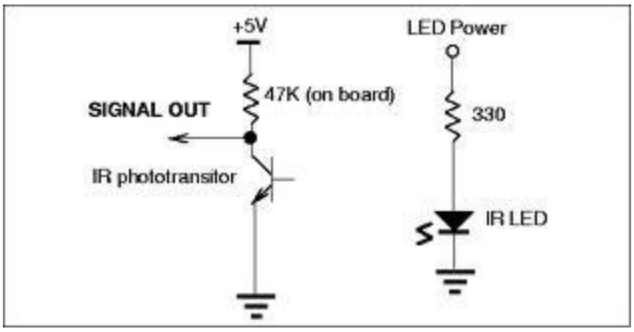


Figure [3.3] phototransistor diagrams [4]

A phototransistor works just like a normal (NPN) transistor, where the BASE current is multiplied to give the collector current, except that in Phototransistor, the BASE current is controlled by the amount of visible or Infrared light, which is why the device only needs 2 pins.

[3.3.1.4] Block Diagram of Optical Bubble Detector

1. Light Source

The light source used here is infrared LED which is worked as a transmitter. Infrared LED responsible to transmit light through tubing to the receiver.

2. Photodetector

Phototransistor has been choosing as detector or receiver. The bigger output produce by the phototransmitter, phototransistor eliminates the using of amplifier and makes the circuit simple.

3. Microcontroller

A microcontroller is a highly integrated chip which performs controlling functions. A microcontroller is used to control of the bubble detector operation. Output from the bubble detector circuit was directly connected to the digital port of microcontroller with development board named arduino.

The uses of this development board eliminate the requirement of external analog to digital converter (ADC), since this converter can be created in the program.

Figure [3.4] microcontrollers [5]

Advantages of using optical sensor in air bubble detector

1. Greater sensitivity.

2. Electrical passiveness.

3. Freedom from electromagnetic interference.

4. Wide dynamic range.

6. Multiplexing capability.

Disadvantages of using optical sensor in air bubble detector

1. Particulates accumulation lower accuracy over time.
2. Non-Invasive type requires transparent or translucent tube material.
3. Invasive type is exposed to fluid.

[3.3.2] Capacitive sensor

[3.3.2.1] Capacitive Detection Method

Electrical conductivity detectors require a direct electrical connection to the IV fluid. To electrically isolate the patient, this connection must have low leakage current and high dielectric strength. Typically, two or three electrodes are placed in contact with fluid and are excited from an AC and DC source while the current/voltage are monitored.

Air bubble does not conduct electricity, but many IV fluids do. A drawback; however is that some IV fluids do not conduct electricity. Another drawback is that a thin film of fluid connects one electrode to the other where the electrode penetrate the tubing wall can give a false detection of fluid presence.

The tubes are first opened to allow the solution to move in between the capacitor plates and then are closed to keep the liquid in place. The distance between the two plates is nominally fixed at 1 cm with copper wires. The output voltage is then measured via the lead wires connected to the capacitor plates as an air bubble of a given diameter was introduced in the solution contained between the capacitor plates.

Air bubble with different diameters was used in order to investigate the change in capacitance as a function of the bubble diameter.

The output voltage measured via the lead wires connected to the capacitor plates without air bubble. Air bubbles with different diameters are used in order to investigate the change in capacitance as a function of the bubble diameter.

Air bubble was detected by measuring the change in the output voltage across the capacitor in the circuit.

Air bubble of different diameter; change the capacitance of the capacitor. Furthermore, the output voltage from the circuit increased with increasing air bubble diameter.

The value of the capacitance of the capacitor is theoretically calculated using:

$$C = \frac{\varepsilon_o \varepsilon_R A}{d} \quad \textbf{(2)}$$

Where:

ε_O: is the permittivity of free space .

ε_R: is the dielectric constant.

A: is the area of the two plates.

d: the distance between the two plates.

The mathematical expression which is used to get theoretical result is:

$$V_{Cpeak} = \frac{V_{in}}{(1+(2\pi fRC))^{0.5}} \quad (3)$$

V_{CPEAK} : is the maximum output voltage from the capacitor.

V_{IN}: is the output voltage from the signal generator.

f: is the frequency applied in the circuit.

R: is the resistance of the resistor.

C: is the capacitance of the capacitor.

[3.3.2.2] Parallel plate Capacitive Theory

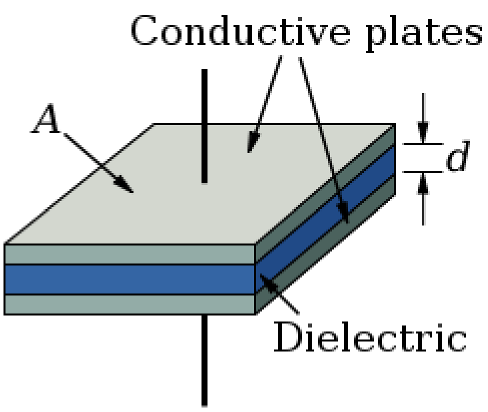


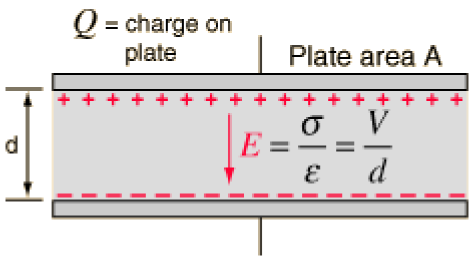
Figure [3.5] Parallel Plate Capacitor [6]

The capacitance of flat, parallel metallic plates of area A and separation d is given by the expression above where:

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \quad (4)$$

$\varepsilon_0 = 8.854 \times 10^{-12} F/m$

The Farad, F, is the SI unit for capacitance, and from the definition of capacitance is seen to be equal to a Coulomb/Volt.



The electric field between two large parallel plates is given by

$$E = \frac{\sigma}{E} \qquad \textbf{(5)}$$

Where σ: charge density

ϵ: permittivity

$$\sigma = \frac{Q}{E}$$

[3.3.2.3] Frequency Effect of Capacitance

When a DC voltage is applied to a capacitor, the capacitor itself draws a charging current from the supply and charges up to a value equal to the applied voltage.

When a supply voltage is reduced the charge stored in the capacitor also reduces and the capacitor discharges. In a circuit were the applied voltage signal is continually changing from a positive cycle to a negative cycle at a rate that is determined by the frequency (a sine wave voltage), the capacitor is either being charged or discharged on a continuous basis. As the capacitor charges or discharges current flows through it which itself is restricted by the internal resistance of the capacitor. This internal resistance is known as Capacitive Reactance and is given the symbol X_C in ohms.

Capacitive Reactance varies with frequency so any variation in frequency will have an effect on the capacitor. As the frequency applied to the capacitor increases its reactance decreases and as the frequency decreases its reactance increases. This variation is called its complex impedance.

$$Xc = \frac{1}{2\pi fC} \quad \textbf{(6)}$$

Capacitive reactance formula where:

Xc = Capacitive Reactance in Ohms, (Ω)

π = 3.142

f = Frequency in Hertz, (Hz)

C = Capacitance in Farads, (F)

Advantages

1. Invasive.

2. Capacitance is not affected by a particulate accumulation on tube or pipe.

3. Tube or Pipe can be any material.

Disadvantages

1. All bubble are not easy detectable.

2. Must be calibrated to the specific tubing material.

3. Cost.

[3.3.3] Ultrasonic sensor

[3.3.3.1] Ultrasonic Detection Method

Ultrasonic detectors are the most widely used in the IV medical fluid delivery field and are based on the fact that sound is more readily conductive through liquid than through air. Thus, can air bubble does not "conduct" sound from one side of the tubing wall to the other, while fluid does conduct sound. Ultrasonic detectors are effective at detecting small amount of gas in IV tubing, but have a number of drawbacks. They are expensive. They required that the tubing be in direct contact with the ultrasonic transmitter and receiver.

Moreover, the slightest air gap can trigger the detector, causing a false alarm and micro bubbles that build up on the surface of the tubing are too small to be harmful also can trigger false alarm, since the micro bubbles, despite of their very small size, still provide a boundary to the ultrasound. In addition, ultrasonic detectors have fairly high power consumption, greater than 100 mw.

In ultrasonic air bubble detector there are two piezoelectric crystals that are mounted in housing on each side of the slot one of the piezoelectric crystals is electrically excited at its resonant frequency to produce ultrasonic sound waves that are directed transversely through the IV line toward the other piezoelectric crystal. The other crystal resonates at approximately the same ultrasonic frequency as the transmitting crystal, and in response to the ultrasonic sound waves that is received, produce a corresponding electrical output signal. Since liquid is much better conductor of ultrasonic sound than air, any gaseous bubbles entrained in the liquid that flows through the IV lines between the transmitting and receiving piezoelectric crystals will attenuate the ultrasonic sound waves which is reaching the receiving crystal in a manner indicative of air bubble size and density changes in the magnitude of the ultrasonic sound waves received produce a corresponding change in the electrical signal output from the receiving crystal. A monitoring circuit is coupled to the receiving crystal and responds to the electrical output signal.

This monitoring circuit typically stops the pump and produces an audible alarm if either too many air bubble.

In pulsing ultrasound applications, the propagation velocity of sound requires ultrasound pulses to be at least 10-20 micro second a part for a fast-moving 1.25 cm diameter bloodstream, so that tracking is not continues.

In order to detect air bubbles, the attenuation of the ultrasonic transmission line changes as soon as air bubble enters the tube located between the ultrasonic transmitter and the ultrasonic receiver.

[3.3.3.2] Definition of ultrasonic waves

The ultrasonic waves are the ultrasound waves. The band of the frequency of ultrasonic waves lies above 20 KHz, which is above the band of frequency that human beings can hear. Thus thought the ultrasonic waves exist in atmosphere, they cannot be heard.

As all signals it has a characteristic which is represented by one cycle.

1- υ: The number of cycles per unit time introduced into the medium each second.

2- The maximum height of the wave cycle is the amplitude of ultrasound wave.

3- λ :The distance between two peak is the wave length .

The speed of transmission of ultrasonic waves depends on the media through which they are passing. In most of the cases where ultrasonic waves are used in the instruments, the waves have to travel through the air, where their speed is affected by environmental factors like temperature of the air, the existing humidity, and the turbulence of air. One of these, the temperature of the air has major impact on the speed of the ultrasonic waves.

The speed of ultrasound can be represented by an equation that depends on the wave length and frequency:

$$C = V \times \lambda \qquad \textbf{(7)}$$

Ultrasound wave speed formula where:

c=ultrasound wave speed.

υ=ultrasound frequency.

λ=ultrasound wave length.

In different media the speed changes dependently on the changes in the wave length at relatively constant speed.

The ultrasound speeds in some materials:
Blood: 1570 m/sec.
Air: 331 m/sec.
Bones: 3360m/sec
Muscle: 1570m/sec
Fat: 1480m/sec

Which indicates that the ultrasound wave speed is relatively high in solids material and intermediate in liquids and low in gases materials.

The ultrasound waves that is transmitted through different media depends on the acoustic impedance which is referred to the reflection of the ultrasound wave that means each media has it's own impedance that can be expressed by:

$$Z = \rho \times C \qquad \textbf{(8)}$$

The acoustic impedance formula where:

Z: the acoustic impedance.

ρ: The density of the medium.

c: The speed of ultrasound wave.

Dependent on acoustic impedance for each media we can determine the reflection coefficient and transmission coefficient for ultrasound wave through it and they can be expressed by:

$$\alpha_R = \frac{Z_1 - Z_2}{Z_1 + Z_2} \qquad \textbf{(9)}$$

$$\alpha_T = (Z_1 Z_2 /(Z_1 + Z_2)^2) \qquad \textbf{(10)}$$

Where: Z_1 and Z_2 are the acoustic impedance of the two medium.

α_R= The reflection coefficient .

α_T= The transmission coefficient .

Strength of acoustic reflection increases as difference in Z increases. The unit of acoustic impedance is the Rayl (Kg m^{-1} $s^{-1)}$.

The acoustic impedance of blood (0.0004×10^6), blood (1.61×10^6) and water (1.48×10^6).

Which thy give an equation collect both of them:

$$\boldsymbol{\alpha_R+\alpha_T=1} \qquad \textbf{(11)}$$

Some values of acoustic impedance for some materials:

Air at standard temperature and pressure 0.0004Kg/m^2 sec

Blood: 1.16 Kg/m^2 sec

Skull bone: 6.10 Kg/m^2 sec

[3.3.3.3] Behavior of ultrasonic waves

Changes in ultrasonic wave's propagation velocity and wave attenuation can be related to the change in the physical properties of a material.

Attenuation is loss of energy, expressed as change in intensity, as the energy travels through a medium. Ultrasound intensity is measured in watts per square centimeter. Decibels are used to express difference between ultrasound intensities.

Ultrasound velocity decreased linearly with increasing temperature with thermal coefficient -2.2m/s/degrease C and the attenuation increased with increasing temperature, with thermal coefficient +0.75dB/MHZ/degrease.

[3.3.3.4] Ultrasonic Velocity

The velocity of propagation of an ultrasonic wave is independent of wave frequency and depends on the characteristic and loading condition of the material through which it moves.

While a few different methods for measuring the time for a propagation wave to travel a known distance. In general, the velocity of an ultrasonic wave V as it propagates through a medium can be expressed simply as the distance traveled by the wave d from an ultrasonic source to an ultrasonic receiver, over a given period of time t.

$$V = \frac{d}{tf - ti} = \frac{d}{t} \qquad \textbf{(12)}$$

The air bubble has acoustic impedance that will make a higher attenuation for the ultrasound wave. In the presence of air bubble the amplitude of the ultrasound waves will attenuate (decrease). On the other hand when the air bubble size increases the time will increase and the velocity will decrease $V = \frac{d}{t}$.

[3.3.3.5] Calculating Distance with Ultrasound

Distance traveled (d) =speed(s) ×time (t)

Speed of sound in air = approximately 334 meters per second

Speed of sound in water = approximately 1530 meters per second

Speed of sound in blood is 1500 meters per second

The time is take to detect an object by ultrasound is equal to the time it takes for the ultrasound wave to be emitted, bounce off an object and return to the detector. So, we need to halve this time when using the equation above.

[3.3.3.6] Calculating Amplitude with Ultrasound

We consider A_0 to be the wave amplitude at some starting position $X=X_0$ and A as the reduce amplitude of the wave after traveling some distance X, the relationship between the distance and amplitude is given by the equation

$$A = A_0 e^{-AX} \qquad \textbf{(13)}$$

α: Is a frequency dependant attenuation coefficient.

[3.3.3.6] Ultrasonic Transducer

The devices that use ultrasonic waves for the measurement of certain parameters are called as the ultrasonic transducers. The measurement devices using the ultrasonic waves comprise of the two major parts. One part of the device transmits the ultrasonic waves and the other part of the devices receives the ultrasonic waves.

The devices are transmitting and the receiving the ultrasonic waves may be located at the two opposite ends. In some cases the transmitting and the receiving devices are located at the same end and on the same side. In such cases the sending device emits the ultrasonic waves, which strike some obstacle, get reflected from there and come back to the sending end where they are received by the receiving device.

No matter what the arrangement of the transmitting and the receiving device is, there is a timer that measures the time difference between the sending of the ultrasonic waves and recipient of the ultrasonic waves. This time is calibrated against the parameter to be measured. Thus the speed of the ultrasonic waves is an important property based on which the transducers are using these waves work. In some ultrasonic transducers, instead of the speed, the change in the phase or frequency of the transmitting and the receiving ultrasonic waves is used as the basis for the measurement of the parameter.

The ultrasonic transducers are used commonly for the measurement of flow rate of the fluids, the level of the liquid, displacement and detect the object.

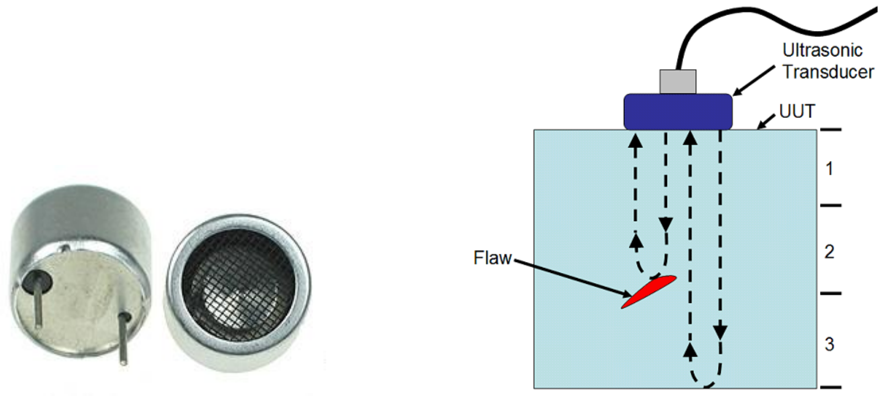


Figure [3.6] Ultrasonic Transducer [7]

The piezoelectric crystal is one of the most commonly used elements in the ultrasonic transducers. It can be used as the both, transmitting as well as the receiving device, in the transducers. It is enclosed within the casing so that it can work efficiently and securely.

The piezoelectric crystals can work in the frequencies ranging from 20 KHz to 15 MHz. The voltage passed through these devices generates the ultrasonic waves.

[3.3.3.7] Basic component of Ultrasonic

[3.3.3.7.1] Transmitter and Receiver

Ultrasonic transmitter is a transmitter which produces emissions in the ultrasonic range, at a frequency too high for the human ear to detect. Ultrasonic transmitters should not be confused with ultrasonic transceivers, which are capable of transmitting and receiving information in the same unit. Ultrasonic Receiver detects the signal from the Ultrasonic Transmitter.

1. Ultrasonic Transmitter

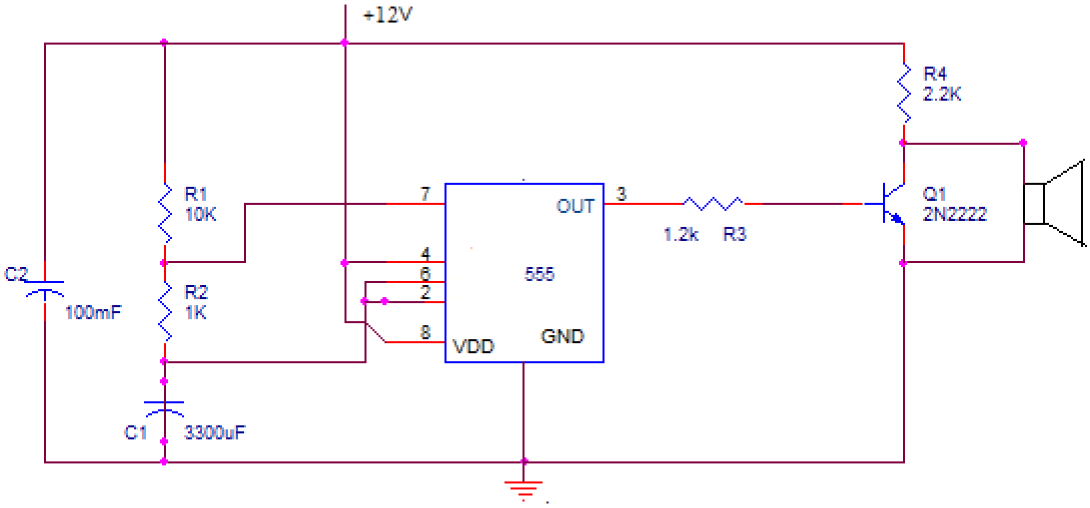


Figure [3.7] ultrasonic transmitters [8]

The circuit is used to transmit ultrasonic waves through air, which are intended to be picked up by a matching ultrasonic receiver.

The circuit uses a 555 timer IC configured as and a stable multivibrator, it generates a continuous signal of a set frequency as long as its reset pin (pin 4) is held high.

Since the ultrasonic transducer used in this circuit is one designed to vibrate optimally at about 40 kHz, the resistor and capacitor values of the circuit were chosen such that the 555 will output a signal whose frequency is about 40 kHz. This 555 output is amplified by Q1, which drives the ultrasonic transducer. The transducer then vibrates at 40 KHz, generating ultrasonic sound waves of that frequency.

2. 555 timer

The 555 timer is connected to monostable state and fed with the output of the comparator as a trigger.

$$T = 1.1 \times R \times C \tag{14}$$

The frequency is calculated by

$$f = \frac{1.44}{(C_1(R_1 + 2R_2))} \tag{15}$$

Wherein f is in Hz if R1 and R2 are in mega ohms and C1 is in microfarads.

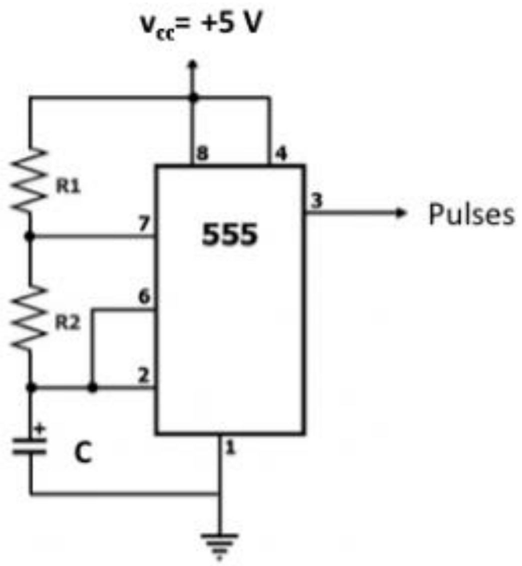


Figure [3.8] 555 timer circuit [9]

3. Ultrasonic Receiver

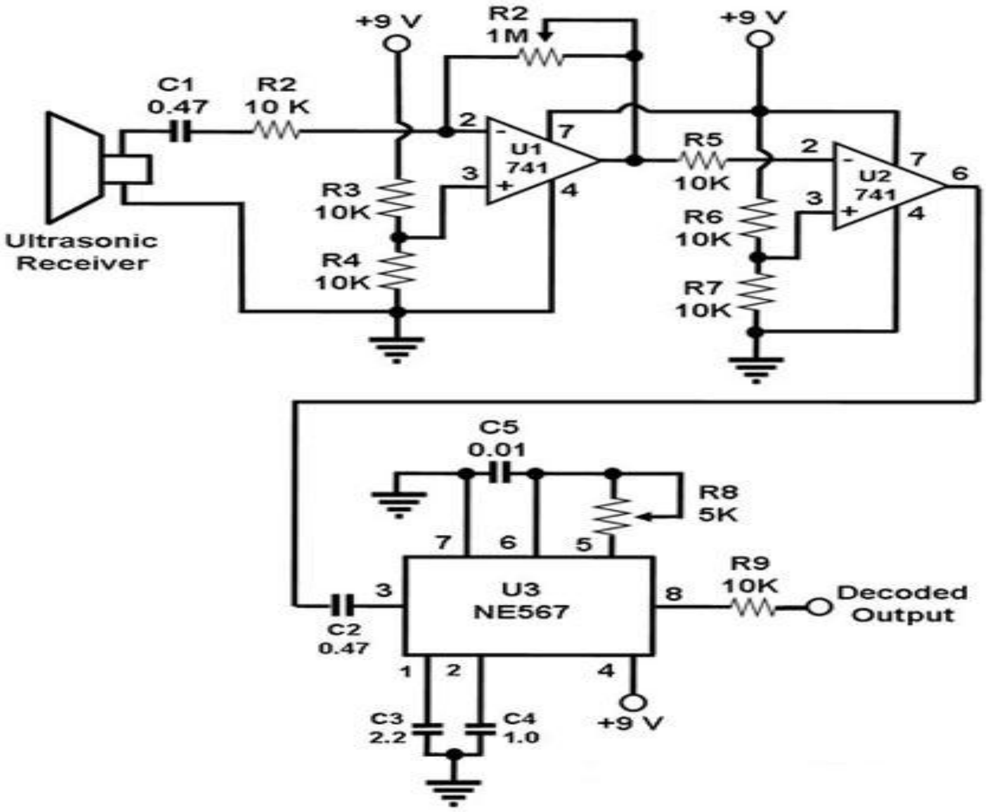


Figure [3.9] Ultrasonic Receiver [10]

This circuit is used to receive ultrasonic waves from the air that were transmitted by a matching ultrasonic transmitter.

Since the ultrasonic receiver used in this circuit is one designed to vibrate optimally at about 40 kHz, the transmitter paired with this receiver must also transmit 40 kHz waves. When these waves hit the receiver, the receiver vibrates and produces electric impulses, also at 40 kHz. These electric signals are amplified by the two op amps in the circuit, the amplified output of which are fed into the 567 IC. This is a PLL tone decoder, it outputs a signal if it detects an input that is tuned to its set frequency (40 kHz in this case).

[3.3.3.8] Ultrasonic Sensor Types:

1- Level sensors .
2 -Flow sensors .
3- Air in line sensors / bubble detectors .

1. Ultrasonic Level sensors

Ultrasonic level sensors measure the distance between the transducer and the surface using the time required for an ultrasound pulse to travel from a transducer to the fluid surface and back to the transducer .These sensors use frequencies in the tens of kilohertz range; transit times are ~6 ms/m. The speed of sound (340 m/s in air at 15°C (1115 fps at 60°F) depends on the mixture of gases in the headspace and their temperature. While the sensor temperature is compensated for this technology is limited to atmospheric pressure measurements in air or nitrogen.

Ultrasonic level sensors are not susceptible to error due to the target material's color, shape or composition (e.g., transparent or opaque, liquid or solid). The ultrasonic level sensors are particularly good for applications that must sense a non-metallic object in an environment where there is systematic, heavy wash down, liquid, dust, heavy spray, food, ink, or other environmental hazards. Since the ultrasonic level sensor's sound energy is used for detection, the reflecting object does not have to be metal, but can also be glass, plastic or even paper.

Characteristic of Ultrasonic Level sensors:

1. Accurate and reliable sensing method.
2. Ideal technology for difficult fluids.
3. Sized and priced for most applications.
4. Simple to use.

2. Ultrasonic flow measurement

Ultrasonic flow measurement sensors are suitable for measuring both liquid and gas flow. The key advantage is that there are no moving parts and can be designed to be non-invasive.

Ultrasonic flow meters use sound waves to measure the flow rate of a fluid. Doppler flow meters transmit ultrasonic sound waves into the fluid. These waves are reflected off particles and bubbles in the fluid. The frequency change between the transmitted wave and the received wave can be used to measure the velocity of the fluid flow. Time of Flight flow meters use the frequency change between transmitted and received sound waves to calculate the velocity of a flow.

Each Doppler flow meter utilizes two piezoelectric crystals contained within either two separate transducer heads one transducer head or the probe tip of the insertion model. Sound is transmitted from one of the crystals, reflected by useful sonic reflectors suspended within the liquid and recorded by the receiving transducer. If the reflectors are moving within the sound transmission path, sound waves will be reflected at a frequency shifted (Doppler shift) from the transmitted frequency. The difference between the reflected frequencies and transmitted frequencies is directly proportional to the speed of the sonic reflectors, resulting in a liquid flow rate that is converted to various users defined measuring units.

Doppler shift:

$$F_d = \frac{2\,fv\cos t}{c} \qquad \textbf{(16)}$$

Where, V is the blood flow velocity.

θ is the incident angle of the ultrasound wave .

C is the velocity of sound in blood.

F is the incident ultrasound frequency.

Advantages

1. Non-Invasive ultrasonic wave used for bubble detection.

2. Highly Precise: straight line of sight between transmitter and receiver.

3. Particulate accumulation will not effect bubble detection.

4. Can be used with any tubing type.

5. Able to accurately evaluate the size of bubble.

6. Ultrasound can distinguish between micro air and tiny blood clot so it affects on its accuracy.

Disadvantage

1. The sensor is expensive.

4

Electrical design

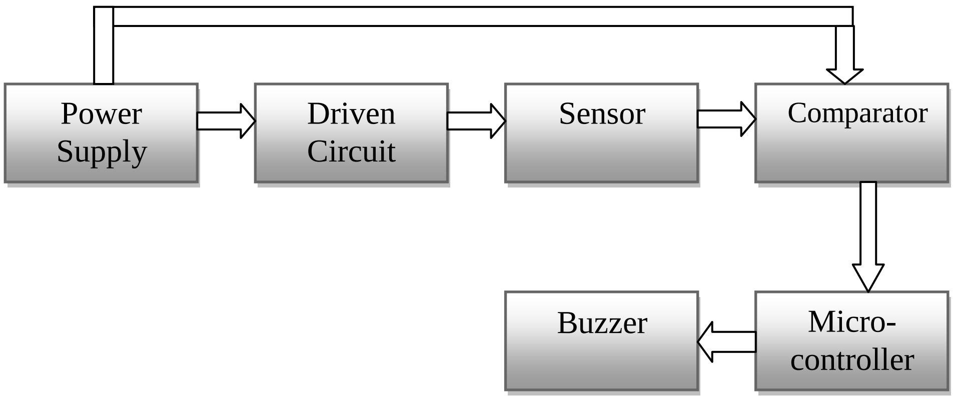
Chapter Four

Electrical Design

[4.1] Introduction

This chapter talks about the detailed of design and explain the major part of the system, and explain the main characteristic that will make the project to operate.

[4.2] Block diagram of ultrasonic air bubble detector



[4.2.1] Power Supply

The power supply circuit can be divided into four stages: transformation, rectification, filtering and regulating.

1. Transformation is accomplished by the transformer which steps down the 220 volts to desired volt AC sources. The transformer also electrically isolates the load from the utility power line by using magnetic coupling to transfer the power.

2. Rectification is accomplished by the diode bridge configuration. A bridge rectifier is actually two full wave rectifiers. The right side of the bridge provides positive full wave rectification while the left side provides negative full wave rectification.

$$V = \frac{2V\max}{\pi} \qquad \textbf{(17)}$$

3. Filtering is provide by capacitor, rectified signal to provide a flat DC voltage equal to the peak of the un-rectified signal. Some ripple occurs on the signal and this is a function of the load and the size of the capacitor.

$$Vc = 1.4 \times Vin \qquad \textbf{(18)}$$

4. The function of the regulator 7805 is to provide a constant output voltage. The input voltage required to maintain desired output of the regulator must be greater than line regulation of the regulator. Then the transformer must have a peak voltage in good range.

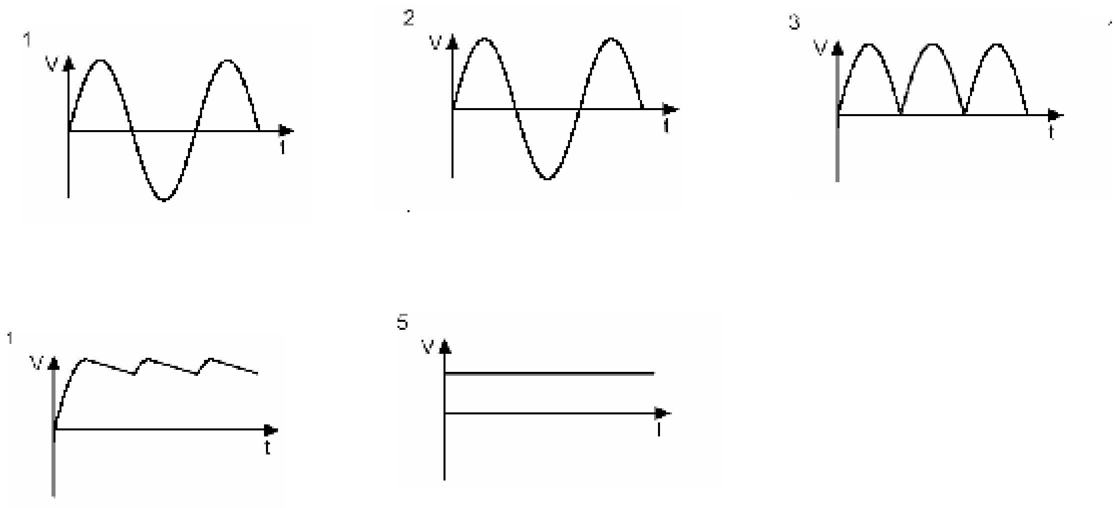


Fig [4.1]: power supply waveform [11]

We chose the value of the capacitor by the principle

1mA ⟶ 1µF

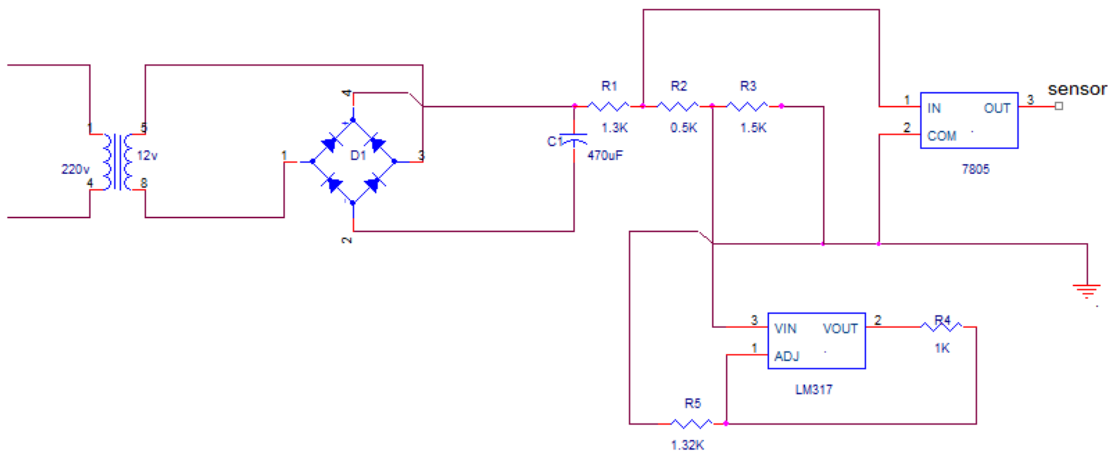


Fig [4.2]: power supply [12]

LM317

In our project we need two voltages one to feed all circuit and the other for the reference that will feed to the comparator, so we use the voltage divider to get the two voltages:

$Voltage_1$ =5v to all circuit.

$Voltage_2$=3v reference to the comparator.

So we by the experience of the project we see the voltage after capacitor is 15v DC, and to get the two voltages we do the following:

1-We suppose two voltages and find the values of resistors 3v, 10v.

$3 = \left(\frac{10*R3}{R3+R2}\right)$ Let R_3=.5kΩ

R_2 will be 1166Ω .

$$10 = \left(\frac{15 * R1}{R1 + R2 + R3}\right)$$

R_1 will be 1320Ω .

For the reference voltage we use LM317 to keep it fixed and for this we use the law:

$V_{out} = 1.25 * \left(\frac{R4}{R5} + 1\right)$ Let R_4 =1KΩ **(19)**

R_5 will be 1.4 KΩ .

We depend on the reflection of the ultrasound signal to determine the reference voltage so we use the attenuation coefficient of reflection between water and air and that what we use in experimental part in our project :

1- Water and Air Bubble .

$\alpha_R = \left(\frac{Zw-Za}{Zw+Za}\right)^2$ **(20)**

$\alpha_{R=}$ 0 .995

In this case all the signal will reflection .

2- Water and Tube .

$\alpha_{R2=}\left(\frac{Zw-Zt}{Zw+Zt}\right)^2$

$\alpha_{R2=}0.58$

In this case just 3 volt will pass from 5 volt when there is no air bubble which is the reference.

[4.2.2] Driven Circuit

The driven circuit consists of many component and it insert in the last of this chapter, the component are:

1. TL074BCN:

The JFET input operational amplifier in the TL07x series are similar to the TL08x series, with low input bias and offset current and fast slew rate. The low harmonic distortion and low noise, so it is suitable for high fidelity and audio preamplifier applications. Each amplifier features JFET inputs coupled with bipolar output stages integrated on a single monolithic chip.

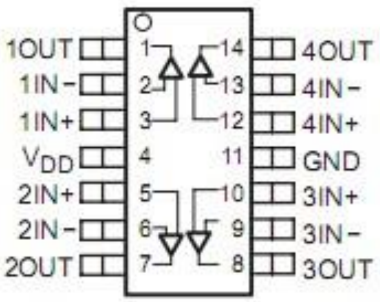


Figure [4.3]: TL074BCN (13)

2. Max636:

The MAX635/MAX636/MAX637 inverting switching regulators are designed for minimum component DC-DC conversion in the 5mW to 500mW range. Low power applications require only a diode, output filter capacitor, and a low-cost inductor. An additional MOSFET and driver are needed for higher power applications. Low battery detection circuitry is included on chip.

The MAX635/636/637 is preset for -5V, -12V, and -15V outputs, respectively. However, the regulators can be set to other levels by adding 2 resistors.

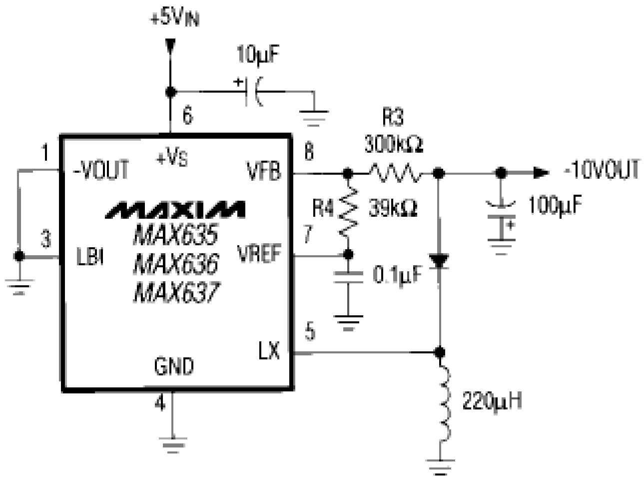


Figure [4.4]: MAX636 (14)

$$V_{OUT} = -1.31 \times \frac{R_3}{R_4} \qquad \textbf{(21)}$$

[4.2.3] Sensor

[4.2.3.1] Ultrasound Air in Line Sensor:

A device for detecting the presence of a gaseous fluid in relation to a predetermined level of liquid in an elastically deformable vessel comprises a U-shaped body capable of accommodating within it a portion of the vessel at a predetermined liquid level. A pair of piezoelectric transducers in the body, used as transmitter and receiver, is fixed face-to-face on opposite arms of the U-shaped body. The device moreover comprises a cover capable of confining the portion of the vessel inside the U-shaped body, and an elastic device disposed between the cover and the U-shaped body and capable of producing an elastic deformation of the vessel and causing the contact surfaces of transducers to contact intimately the said portion of the vessel without entrapment of air.

Non-invasive bubble sensors are ideal for critical applications where air or gas bubbles require detection through rigid or flexible tubing.

Typical applications can be found in many patient-connected medical devices such as transfusion systems, blood processing equipment, dialysis machines and infusion pumps.

Further, air bubble sensors can also be utilized in chromatographs, analytical instruments and dispensing or liquid filling machines.

Inclusions in a liquid flow, such as air bubbles in a blood flow, are detected by transmitting a signal through the fluid and receiving and interpreting the received signal based on the expected degree of attenuation for the liquid and the inclusions. The amplitude of the transmitted signal is automatically adjusted to maintain constant average amplitude of the detected signal, thus compensating for changes in the detection environment. The output voltage of receiver is compared to the reference voltage and the output of comparator will goes to microcontroller, if there are micro bubbles so the microcontroller will give an output so the alarm will work and if no bubbles so the alarm will not work .

[4.2.4] Comparator

They are used to compare two voltages. When one is higher than the other, then the comparator circuit output is in one state for example +Vcc, and when the input conditions are reversed, then the comparator output switches to the other condition. Usually one of the terminals used for input signal voltage and the other is used to set the reference voltage that we need to make the comparison.

The threshold voltage for this comparator is zero volt which means that if the input voltage is zero, the output will be zero and if it's greater than zero, it will be high (+Vcc). And this is the high voltage that will be used to operate the next alarm circuit.

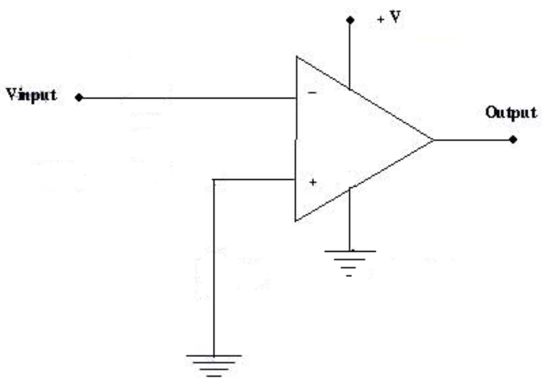


Figure [4.5]: Comparator [15]

[4.2.5] Microcontroller

A microcontroller (also micro computer, MCU or µc) is a small computer on a single integrated circuit consisting internally of a relatively simple CPU, clock, timers, I/O ports, and memory. Microcontrollers are designed for small or dedicated applications. Thus, in contrast to the microcontroller used in personal computers and other high performance or general purpose applications, simplicity is emphasized. Some microcontrollers may use four bit words and operate at clock rate frequencies as low as 4KHZ, as this is adequate for many typical applications, enabling low power consumption (mill watt or microwatts), they will generally have the ability to retain functionally while waiting for an event such as a button press or other interrupt; power consumption while sleeping (CPU clock and most peripherals off) may be just nanowatts, making many of them serve performance critical roles, where they may need to act more like a digital signal processor (DSP), with higher clock speeds and power consumption.

[4.2.5.1] Types of Microcontroller:

1. Flash device:

Can be reprogrammable by the programmer.

2. One Time Programmable device (OTP):

Once programmed cannot be reprogrammed. All OTP devices however do have a windowed variety, which enable them to be erased under ultra violet light in about 15 minutes, so that they can be reprogrammed.

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[4.2.5.2] Microcontroller Architecture Contents:

1. Microprocessor.
2. Memory.
3. I/O.

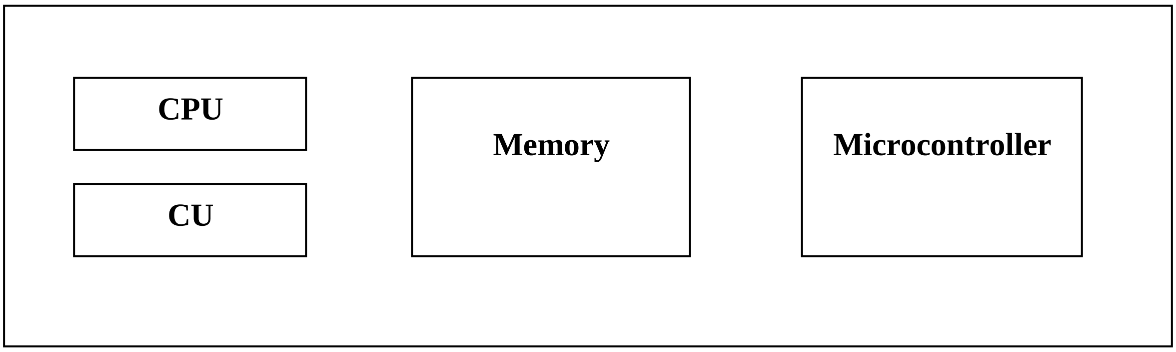

Figure [4.6]: The Simplest Microcontroller Architecture (16)

[4.2.5.3] Hardware Features of Microcontrollers:

1. Supply Voltage

Most microcontrollers operate with the standard logic voltage of 5V. Some microcontrollers can operate at as low as 2.7V and some will tolerate 6V without any problem.

2. Clock

The clock is usually provided by connecting external timing devices to the microcontroller. Some microcontrollers have built in timing circuits and they do not require any external timing components.

3. Timers

A timer is basically a counter which is driven either from an external clock pulse or from the internal oscillator of the microcontroller. Most timers can be configured to generate an interrupt when they reach a certain count (usually when they overflow).

4. Watchdog

The watchdog is basically a timer which is refreshed by the user program and a reset occurs if the program fails to refresh the watchdog the watchdog timer is used to detect a system problem, A watchdog is a safety feature that prevents runaway software and stops the microcontroller from executing meaningless and unwanted code.

5. Reset input

A reset input is used to reset a microcontroller, resetting puts the microcontroller into a known state, an external reset can be done by connecting a push button switch to the reset input.

6. Interrupts

An interrupt causes the microcontroller to respond to external and internal events very quickly, when an interrupt occurs the microcontroller leaves its normal flow of program execution and jump to a special part of the program.

7. Brown –out detector

They reset a microcontroller if the supply voltage falls below a nominal value, they can be employed to prevent unpredictable operation at low voltage especially to protect the contents of EEPROM-type memories.

8- Analogue –to-converter

(A/D)is used to convert an analogue signal such voltage to a digital form so that it can be used by a microcontroller ,A/D converter usually generates interrupt when a conversion is complete so that the user program can read the converted data quickly .

A/D converters are very useful in control and monitoring applications since most sensors (e.g. temperature sensor, pressure sensors, force sensors, etc.) produce analogue output voltages.

9. Serial I/O

Serial communication enables a microcontroller to be connected to another microcontroller or a PC using a serial cable.

10. EEPROM data memory

The advantage of an EEPROM memory is that the programmer can store nonvolatile data in such a memory, and can also change this whenever required.

11. LCD drivers

It enables a microcontroller to be connected to an LCD display directly, these druvers are common since of the function provided by them can be implemented in software.

12. Analog comparator

Are used where it is required to compare two analogue voltages.

13. Real-time clock

It enables a microcontroller to have absolute date and time information continuously.

14. Sleep mode

The main reason of using the sleep mode is converse the battery power when the microcontroller is not doing anything useful. The microcontroller usually wakes up from the sleep mode external reset or by a watchdog time-out.

15. Power–on reset

Keep the microcontroller in reset until all the internal circuitry has been initialized.

16. Low power operation

It is important in portable application where the microcontroller based equipment is from batteries.

[4.2.5.4] Microcontroller PIC18F4550

The PIC is the heart of the board. It's a programmable microcontroller with 32Kbytes of flash program memory and 2kbytes of general purpose SRAM. It has 13 A/D inputs and 18 general purpose I/O ports. On the CUI board, one of the general purpose I/O pins is dedicated to the "program" button to enter bootloading mode.

This is a 40 pin PIC Microcontroller consisting of 5 I/O ports (PORTA, PORTB, PORTC, PORTD and PORTE). PORTB and PORTD have 8 pins to receive/transmit 8-bit I/O data. The remaining ports have different numbers of pins for I/O data communications.

Features of PIC18F4550 Microcontrollers:

1-Low power consumption (nano Watt Technology).

2-Has different pin layout (40 and 44 pins).

3-High Performance and speed up to 12Mb/s in Full speed mode and 1.5Mb/s in low speed mode.

4-Accuracy of 10-bit to convert analog signal to digital number relatively.

5-Up to 13 analog to digital converter model channels with programmable accusation time.

6-The PIC18F4550 incorporates a Universal Serial Bus interface that is V2.0 compliant supporting both 1.5Mb/s low speed and 12Mb/s full speed communications.

7- 32K bytes of program memory.

8- 2048 bytes of SRAM.

9- 256 bytes of EEPROM data memory.

[4.2.6] Buzzer

Specification:

1. Voltage: 5V
2. Size: 32×15.5mm
3. Sound at 30cm: 70dB

Features:

1. Low pitch sound, medium sound output.
2. Low current consumption.
3. Externally duration, long life.

4. Ultra small size, easy to install.

Figure [4.7]: Buzzer (17)

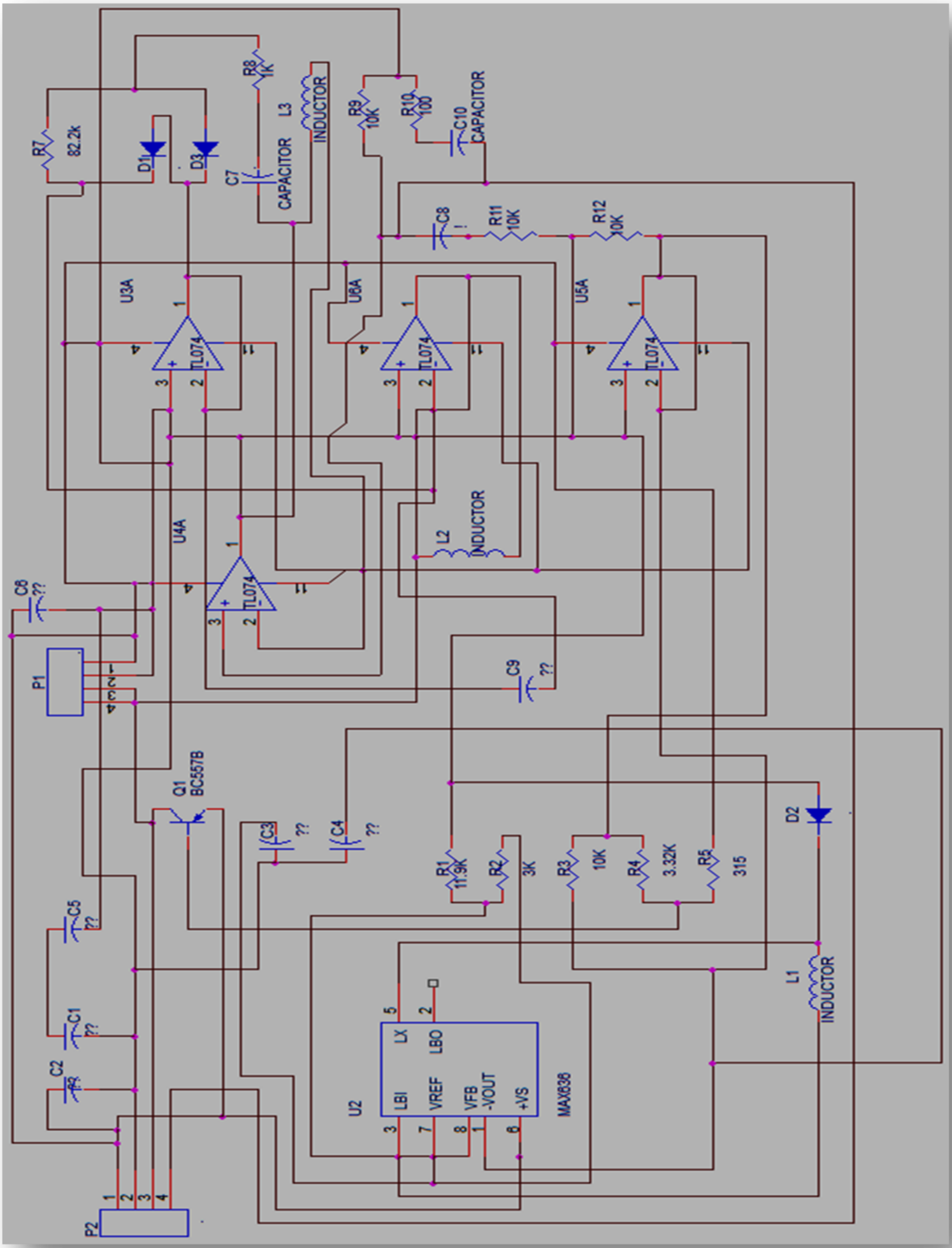

Figure [4.8]: Driven Circuit (18)

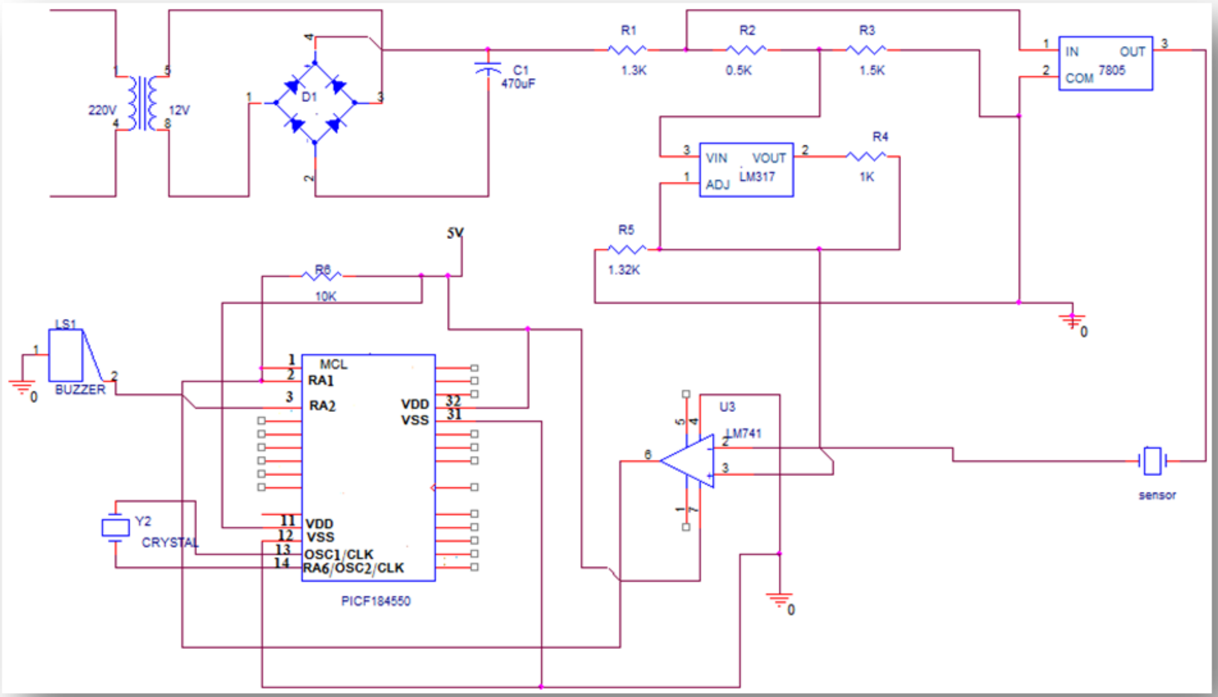

Figure [4.9]: Circuit (19)

5

Software

Chapter Five

Software

[5.1] Introduction

This chapter includes the software code that we use it in our project, this code wrote in C language.

[5.2] Software Code

```
#include<p184550.h
#pragma config FOSC=INTOSC_XT
#pragma config LVP=OFF
#pragmaWDT=OFF
#pragma config DEBUG=OFF
Void main (void)
{int k=0;
ADCON1=OxOE;
TRISAbits.TRISA1=1;
TRISAbits.TRISA2=0;
k=PORTAbits.RA1;
PORTAbits.RA2=k
}
```

6

System Implementation

Chapter Six

System Implementation

[6.1] Introduction

This chapter demonstrates the methods and procedures used to implement, test, and examine the system operation and behavior.The testing is an important step in implementation the system.

[6.2] Procedure

To make the test we do the following steps:
Take the Water sample:

1. Put it in the tube
2. Put the tube in the sensor

[6.3] Result

After finishing the building of project we test the blood sample by using a LED

1. When there is an air bubble the LED will be on

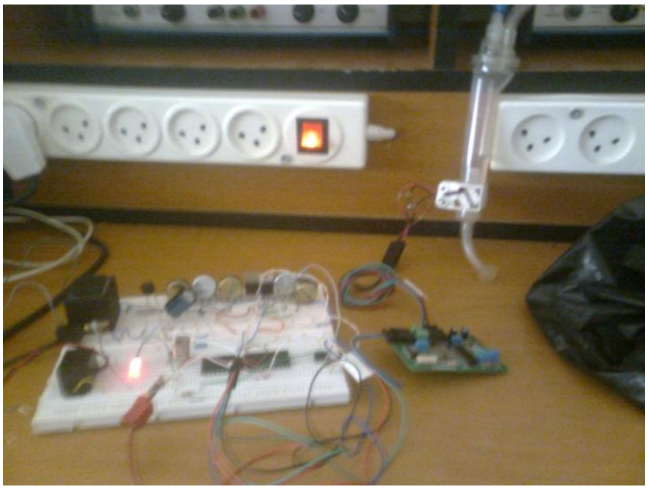

Figure [6.1]: LED ON (20)

2. When there is no air bubble the LED will be OFF

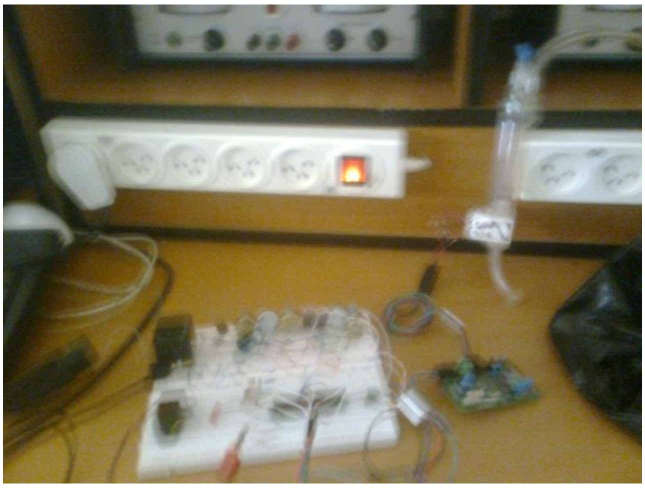

Figure [6.2]: LED OFF (21)

7

Conclusion and Future Work

Chapter Seven

Conclusion and Future Work

[7.1] Conclusion:

In our project we used an Ultrasound sensor and comparator to compare between two values one is the reference and the other from the sensor and gives output that will inter to PIC microcontroller to get an output that will give alarm from the buzzer.

[7.2] Challenges:

During the design of the project, we face many challenges which are:

1. In our project we face a major problem is to get the sensor which is the main part in the project.
2. The driven circuit for this sensor is industrial monopoly and we cannot know how it is working.
3. The sensor is very expensive and not found in markets or in the companies inside Palestine.
4. Less information can get about this type of ultrasound sensor.

[7.3]Recommendations:

After the complete of the project and get the objectives, we recommended for future work:

1. Using the same sensor for detection air bubble and removing it.
2. We advice not to use this sensor one more time because is not available in the marketing.

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Appendices

Datasheet of Project Component