SMART DISTANCE MEASUREMENT DETECTOR

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Electronics)"

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A Report Submitted In Partial Fulfillments of the Requirement of the Degree of Bachelor of Electrical Engineering (Electronics)

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Dedicated, in thousand appreciation for support, encouragement and understandings to my family.

And those people who have guided and inspired me throughout my journey of education.

Thanks for everything…

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.

ABSTRACT

Distance measuring device is a device that is used to measure the length between two points or more. The distance measurement can be little bit difficult if the targets that want to be measured are far from reaching or high. The purpose of this project is to design and create a better distance better distance measurement that can encounter the measuring problem. An ultrasonic measuring device is proposed to solve the problem as the ultrasonic using an ultrasonic sound. The ultrasonic transducer is operating at frequencies in between 40 kHz to 250 kHz. The concept for the project is using the LCD screen and displayed the reading of distance measured and user can use switch button when measure value is taken. In the circuit, there have “Send”, “Store”, “Mask” and “Recall” switch. Besides that, the project using PIC16F84A, which treated as the main component in hardware part, that can save up to 32 measurements, where the PIC will control the whole operation of the circuit while the measurement is executed.

ABSTRAK

Alat mengukur jarak adalah peralatan yang digunakan untuk mengukur jarak di antara dua tempat atau lebih. Pengukuran secara manual akan sedikit rumit jika jarak ukuran yang ingin dibuat adalah terlalu jauh ataupun tempat tinggi. Tujuan projek ini direkabentuk dan dicipta adalah untuk menangani masalah pengukuran jarak dan membolehkan pengukuran jarak yang lebih. Alat pengukur yang dicadangkan menggunakan peranti ultrasonik dapat menyelesaikan masalah kerana peranti ultrasonik menggunakan bunyi ultrasonik. Peranti ultrasonik beroperasi pada frekuensi diantara 40 kHz sehingga 250 kHz. Konsep projek ini yang menggunakan skrin LCD untuk memaparkan bacaan jarak yang diukur dan pengguna boleh menggunakan butang suis semasa nilai ukuran diambil. Dalam litar projek ini mempunyai butang suis seperti “Send”, “Store”, “Mask” dan suis “Recall”. Projek ini menggunakan mikro pengawal PIC16F84A, yang dianggap sebagai komponen utama di bahagian perkakasan, yang boleh menyimpan sehingga 32 ukuran, di mana PIC ini akan mengawal keseluruhan operasi litar semasa pengukuran dilaksanakan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Hz	Hertz
A	Ampere
TX	Transmitter
RX	Receiver
CPU	Central Processing Unit
mt	meter
EMI	electromagnetic interference
dB	decibel
V	Voltage
DB	Data Bus
VCC	Collector Supply Voltage
VEE	Emitter Supply
LED	light emitting diode
LM358	Dual Op-Amp
LM7805	Voltage regulator
DC	Direct Current
EEPROM	electrically erasable programmable read-only memory
°	Degrees
mm	milimeter
PIC	Peripheral Interface Controller

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Background

Linear measurement is a problem that a lot of applications in the industrial and consumer market segment have to contend with. Infrared, radar and laser technology had been apply in the distance measurement but it need high cost and the distance that can be measured is short especially for infrared which in a range are less than 1 meter. So, this project does not use the application of those sensors but had implemented the ultrasonic sensor. Ultrasonic technology is one of the solutions used to optimized balance between cost and the device features. The ultrasonic distance measurer is used mainly when a non-contact measurer is required.

The Smart Distance Measurement Detector using PIC is an efficient way to measure distance and check measurement value that is stored in memory, where the device can record and recall 32 distance measurements, allowing several readings to be taken before copying them into paper. Besides, the devices have 4 switches that are:-

- Send – Basic correction mode
- Store – EEPROM measurements clear (timing factors untouched)
- Mask – Mask correction mode
- Recall – clear entire EEPROM data and set default timing factors

The PIC microcontroller (IC2) is the mastermind that controls the whole operation. When prompted by pressing of Send button, the PIC will transmit a series of 40 kHz pulses via the ultrasonic transmitting transducer (TX). The pulses are accurately generated.

1.2 Project Objective

The purposed of these projects are to design and create a suitable electronic distance measuring device. The objectives of the projects are:

- To create an electronic measuring device using PIC16F84A
- To determine the distance of object with ultrasonic sensor for indoor use
- To get an accurate measurement
- To inform user about the total distance by displaying on Liquid Crystal Display (LCD)

1.3 Scope of Project

Project scope is the combination of objectives and requirements necessary in order to make sure that project run in the limited boundary. The scopes of this project are:

- The implementation of ultrasonic sensor into the device
- Design an appropriate program using PIC16F84A microcontroller
- To develop hardware circuit and software programming
- Purposed the usage of Liquid Crystal Display (LCD) for displaying result

1.4 Problem Statement

In the construction field, the usage of electronic measuring device is still not widely used yet. Due to the high cost of these equipments at market, an economic way needs to think of in order to create an accurate measuring device with low cost.

Nowadays, measuring distance is considered as problem in construction field or indoor measuring activities because this task is made by using measuring tape. The problem will occur when using measuring tape where we need at least 2 persons to measure between two distances. Besides, it is not have a perfect accuracy due to parallax and obstacle in their way.

Improvement had been done where some products have infrared light emitters and receivers to determine an object's distance. Other devices have laser-based systems which have improved accuracy and precision. Presently, the detection techniques of laser, radar, and infrared ray have been widely applied at the aspect of obstruction detection and distance measurement. Because of the expensive price, the distance measurement system of laser and radar is only set on the minority of instruments. For infrared sensor, the range of the distance that can be measured is very short with only a range of 4 - 30 cm [1].

Therefore, this project is necessary to do the process of measurement quickly and accurate without doing measurement manually. It also has the advantages to store measurement as many as 32 memories at one time.

1.5 Report Outline

This report consists of five chapters which Chapter 1 cover about the background, problem statement, objectives, project scope and report outline as additional part to summarize for the whole chapter of the report.

There will be discussing on how Ultrasonic works and it's advantages, Microcontroller, CPU, and other related component in this project. The source had been taken from some source such as internet, magazines, encyclopedia and other thesis that have similar problem statement and different approach. All reference had been cited on the last part of this thesis

For the Chapter 3, there will have a discussion about the methodology. Having a clear description of the methods that will be used and accomplish the project objectives to make a strong application even more competitive. For this project methodology, there will have some discussion on how the project was organized and the flow of the system designed. Before developing the prototype, the simulation has been done to make sure that the circuit would be working properly. Thus, it can be divided into two parts, hardware development and software development which involve the overview of PIC microcontroller, circuit and PCB fabrication.

For the Chapter 4, the result and overall discussion will be presented with some of proof. The result are categorized into three parts includes the hardware, software and analysis of the system. Last but not least, Chapter 5 will be having the conclusion to conclude overall results. It is also includes recommendation for the project to improve in near future.

CHAPTER 2

LITERATURE REVIEW

2.1 Ultrasonic Sensor

Ultrasonic (US) sensors are also widely used to measure distances. Thus they have provided a reliable source of obstacle detections. Since they are not vision-based, they are useful under conditions of poor lighting and transparent objects. However, ultrasonic sensors have limitations due to their wide beam-width, sensitivity to specular surfaces, and the inability to discern objects within 0.5 m. Because of the typical specular nature of the ultrasonic waves reflection, only reflecting objects that are almost normal to the sensor acoustic axis may be accurately detected [2].

Most ultrasonic sensors use a single transducer to both transmit the sound pulse and receive the reflected echo, typically operating at frequencies between 40 kHz and 250 kHz. A variety of different types of transducers are used in these systems [3].

Ultrasonic is one of the distances measuring sensors that had been studied. Ultrasonic transducers measure the amount of time taken for a pulse of sound to travel to a particular surface and return as the reflected echo.[4] Typically, an
ultrasonic rangefinder sends a 'ping' and waits to hear an echo. Sound waves propagate from the transmitter and bounce off objects, returning an echo to the receiver (below left). If the speed of sound is known, the distance to an object can be calculated from the time delay between the emitted and reflected sounds. While the principle of calculating distance from the time of travel is simple, there are many limiting factors to consider. Sound diverges very rapidly, so transducers are carefully designed to produce as small a beam as possible. While some applications require a wide beam, a narrow beam improves the range and reduces background interference. There is a direct relationship between beam width and target surface angle: the wider the beam, the greater the possible angle between the transducer and the surface. When the angle is too great (>12 degrees), the reflected beam misses the transducer as Figure 2. While some surfaces may produce scattered diffuse reflections, these are much weaker and are not used for distance measuring purposes.

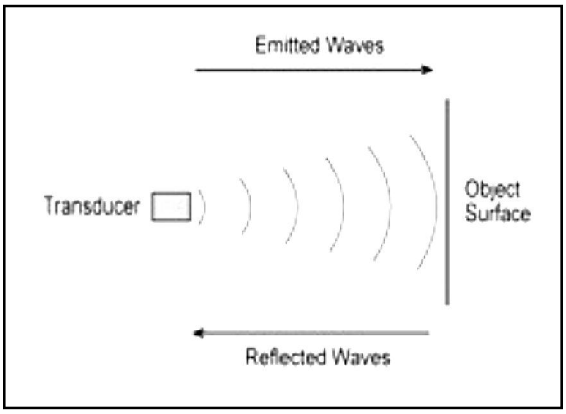

Figure 2.1: An echo received by the transducer

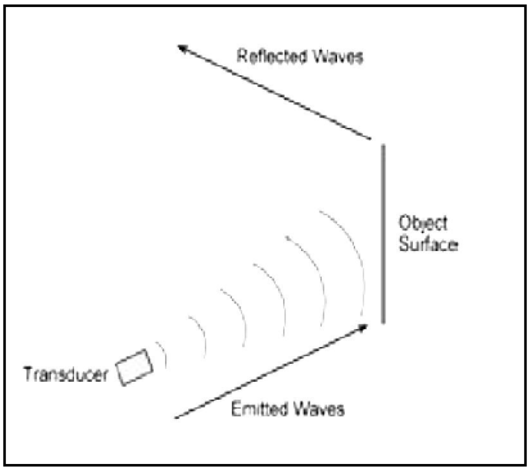

Figure 2.2: Reflected beam misses the transducer

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. Humidity alters the attenuation of sound in air, which determines 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 attenuate more thus reducing the range [4].

The attenuation of sound in air increases with the frequency, and at any given frequency the attenuation varies as a function of humidity. The value of humidity that produces the maximum attenuation is not the same for all frequencies [5].

2.1.1 Advantages of Ultrasonic Sensor

When used for sensing functions, the ultrasonic method has unique advantages over conventional sensors:

i. Discrete distances to moving objects can be detected and measured.
ii. Less affected by target materials and surfaces, and not affected by color. Solid-state units have virtually unlimited, maintenance free life. Can detect small objects over long operating distances.
iii. Resistance to external disturbances such as vibration, infrared radiation, ambient noise, and EMI radiation.
iv. Excellent long term stability
v. Low power consumption and low cost realization
vi. Directional sensitivity
vii. High structural resolution due to large bandwidth
viii. Remote measurement, low interference with objects to be detected, sensitivity to virtually all kinds of objects
ix. Imperviousness to wetness, contamination or wear

2.1.2 Ultrasonic Transducer

There are two main types of transducer used to transmit ultrasonic signals. They are the Piezo type and the electrostatic type. It is even possible to send ultrasonic signals using a conventional high frequency electromagnetic speaker (tweeter) [6].

Figure 2.3: Ultrasonic transmitter and receiver transducer

The general transducer design features a piezo ceramic disc bender that is resonant at a normal frequency of 20 – 60 kHz and radiates or receives ultrasonic energy. They are distinguish from the piezo ceramic audio transducer in that they produce sound waves above 20 kHz which are inaudible to human and the ultrasonic energy is radiated or receive in a relatively narrow beam.

The open type ultrasonic transducer design exposes the piezo bender bonded with a metal conical cone behind a protective screen. The enclosed type transducer design has the piezo bender mounted directly on the underside of the top of cases
which then machined to resonant at the desired frequency. Following are the specifications of ultrasonic.

Specifications:

- Sensitivity : -38dB
- Impedence: >1k
- Operating Voltage: 3V – 20V
- Mounting: solder pad

2.2 PIC Microcontroller

A PIC is a Programmable Integrated Circuit microcontroller, a 'computer-on-a-chip'. They have a processor and memory to run a program responding to inputs and controlling outputs, so they can easily achieve complex functions which would require several conventional ICs. The PIC can received inputs, stored or registers, processed such as added or subtracted and sent out the output.

The PIC microcontrollers are base on RISC (Reduced Instruction Set Computer) architecture; therefore use a relatively small number of instructions. Most PICs used 35 instructions compared to some general-purpose microprocessors (like Motorola 68000 and Intel 8085) that may have several hundred.

Important feature of modern PIC devices is the use of electrically erasable and programmable Flash memory for program storage. These Flash memory devices are often denoted are much easier to work with for one-off prototyping because ensure and reprogramming is greatly simplified

2.2.1 PIC 16F84A

PIC 16F84A perfectly fits many uses, from automotive industries and controlling home appliances to industrial instruments, remote sensors, electrical door locks and safety devices. it is also ideal for smart cards as well as for battery supplied devices because of its low consumption.

EEPROM memory makes it easier to apply microcontrollers to devices where permanent storage of various parameters is needed (codes for transmitter, motor speed, receiver frequencies, etc).

PIC16F84A have total of 18 pins and have the following meaning:

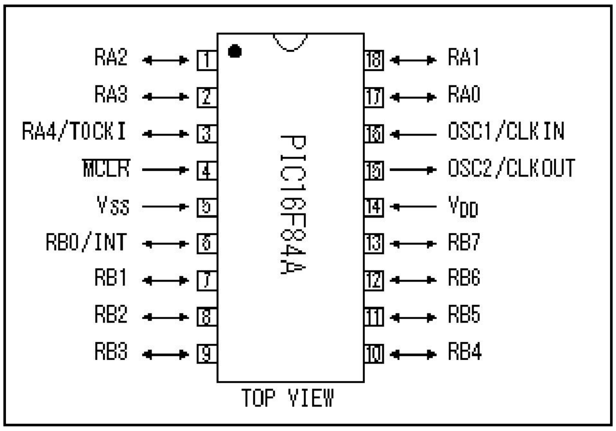

Figure 2.4: PIC16F84A pin description

OSC1/CLKIN: Oscillator crystal input
External clock source input
OSC2/CLKOUT: Oscillator crystal output
Connects to crystal or resonator in crystal oscillator mode
MCLR (inv): Master clear (reset) input
Programming voltage input
This pin is an active low reset to the device

RA0-RA3: Bi-directional I/O port

RA4/TOCKI: Bi-directional I/O port

Clock input to the TMR0 timer/counter

RB0/INT: Bi-directional I/O port

External interrupt pin

RB1-RB7: Bi-directional I/O port

V_{SS}: Ground

V_{DD}: Bi- Positive supply (+2.0V to +5.5V)

2.2.2 Central Processing Unit (CPU)

Central processing unit (CPU) is the brain of a microcontroller. CPU connects all parts of the microcontroller into one whole. Surely, its most important function is to decode program instructions. This transition from a letter to binary form is done by translator such an assembler translator.

Arithmetic logic unit is responsible for performing operations of adding, subtracting, moving (left or right within register) and logic operations. Moving data inside a register is also known as "shifting". PIC16F84A contains 8-bits arithmetic logic unit and 8-bits work register.

PIC16F84A can work with 4 different configurations of an oscillator. Since configurations with crystal oscillator and resistor-capacitor (RC) are the ones that are used most frequently. Microcontroller type with a crystal oscillator has in its designation XT, and a microcontroller with RC pair has a designation RC.

Reset is used for putting the microcontroller into a known condition. That practically means that microcontroller can behave rather inaccurately under certain undesirable conditions. In order to continue its proper functioning it has to be reset, meaning all registers would be placed in a starting position. Reset can also be used when trying out a device as an interrupt in program execution, or to get a microcontroller ready when loading a program [7].

In order to prevent from bringing a logical zero to MCLR pin accidentally, MCLR has to be connected via resistor to the positive supply pole. Resistor should be between 5 and 10k. This kind of resistor, whose function is to keep a certain line on a logical one as a preventive, is called a pull up.

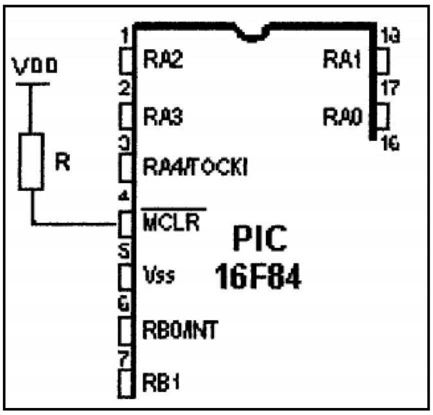

Figure 2.5: The internal reset circuit

Microcontroller PIC16F84A knows several sources of resets:

a) Reset during power on, POR (Power-On Reset)
b) Reset during regular work by bringing logical zero to MCLR microcontroller's pin
c) Reset during SLEEP regime
d) Reset at watchdog timer (WDT) overflow
e) Reset during WDT overflow during SLEEP work engine

2.3 Types of Oscillators

2.3.1 XT Oscillator

Crystal oscillator is kept in metal housing with two ceramic capacitors of 30pF whose other end is connected to the ground needs to be connected with each pin. Oscillator and capacitor can be packed in joint case with three pins. Such element is called ceramic resonator and is represented in charts like the one below. Center pins of the element are ground, while end pin is connected with OSC1 and OSC2 pins on the microcontroller [7].

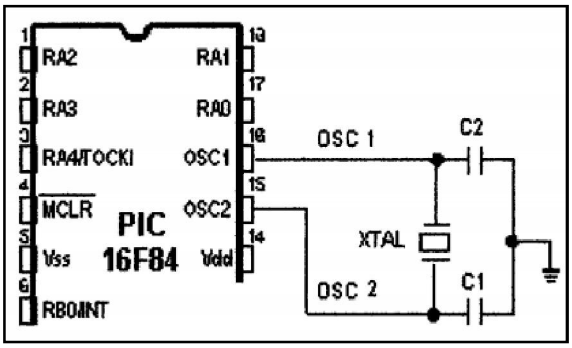

Figure 2.6: Connecting the oscillator

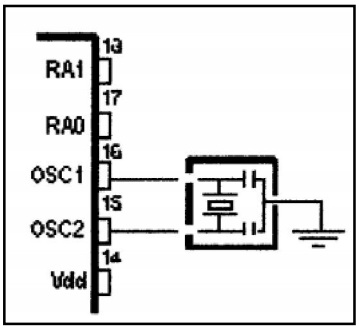

Figure 2.7: Connecting resonator to microcontroller

2.3.2 RC Oscillator

Resonator frequently of RC oscillator depends on supply voltage rate, resistance R, capacity C and working temperature. It should be mentioned here that resonant frequency is also influenced by normal variations in process parameters, by tolerance of external R and C components

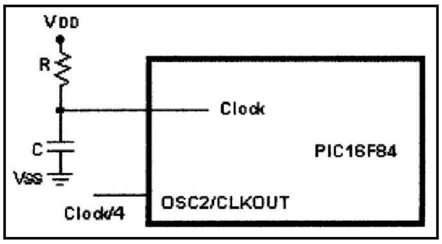

Figure 2.8: RC Oscillator

Above diagram shows how RC oscillator is connected with PIC16F84. With value resistor R being below 2.2k, oscillator can become unstable, or it can even stop the oscillation. With very high value of R, oscillator becomes very sensitive to noise and humidity. It is recommended that value of resistor R should be between 3 and 100k. Even though the oscillator will work without an external capacitor (C=0pF), capacitor above 20pF should still be used for noise and stability. No matter which oscillator is being used, in order to get a clock that microcontroller works upon; a clock of the oscillator must be divided by 4[8]. Oscillator clock divided by 4 can also be obtained on OSC2/CLKOUT pin, and can be used for testing or synchronizing other logical circuits.

2.4 Alphanumeric Liquid Crystal Display (LCD) Module

The measurement reading that calculated by Microcontroller will be send to the LCD to be displayed. Table 2.3.1 below shows the pin connection of the LCD that want to be use.

Table 2.1: LCD pin connection

PIN	NAME	PIN FUNCTION	CONNECTION
1	VSS	Ground	GND
2	VCC	Positive supply for LCD	5V
3	VEE	Contrast adjust	Connected to a preset for contrast adjusting
4	RS	Select register, select instruction or data register	RA2
5	R/W	Select read or write	GND
6	E	Start data read or write	RA5
7	DB0	Data bus pin	RC0
8	DB1	Data bus pin	RC1
9	DB2	Data bus pin	RC2
10	DB3	Data bus pin	RC3
11	DB4	Data bus pin	RC4
12	DB5	Data bus pin	RC5
13	DB6	Data bus pin	RC6
14	DB7	Data bus pin	RC7
15	LED+	Backlight positive input	5V
16	LED-	Backlight negative input	GND

2.5 XTAL

A crystal oscillator is an electronic circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. This frequency is usually use in a wristwatches, to provide a stable clock signal for digital integrated circuits, and to stabilize the frequencies for audio transmitters. The oscillator circuit is dependent on two key conditions; first, the loop gain needs to be greater than losses around the oscillator loop, or equal to unity. Second, the loop phase shift must be equal to 0 or 360 degrees. Loop phase angle shifts determine the frequency at which the oscillator will operate. A change in net loop phase angle results in a change in output frequency of the oscillator circuit. In order to minimize the net phase shift, a quartz crystal is placed in the feedback loop. The crystal used there in is sometimes called a “timing crystal”. On the schematic diagrams, a crystal is labeled with ‘Y’.

Figure 2.9: Actual picture of crystal oscillator

2.6 Integrated circuit (IC) LM358

These devices consist of two independent, high-gain, frequency-compensated operational amplifiers designed to operate from a single supply over a wide range of voltages. Operation from a split also is possible if the difference between the two supplies is 3V to 32V, and V_{CC} is at least 1.5V more positive than the input common-mode voltage. The low supply-current drain is independent of the magnitude of the supply voltage.

Application include transducer amplifiers, dc amplification blocks, and all the conventional operational amplifier circuits that now can be implemented more easily in single-supply-voltage systems. For example, these devices can be operated directly from the standard 5V supply used in digital systems and easily provide the required interface electronics without additional 5V supplies.

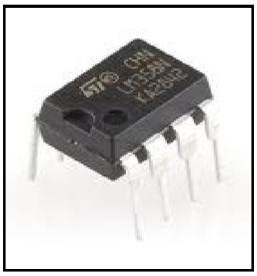

Figure 2.10: IC LM358

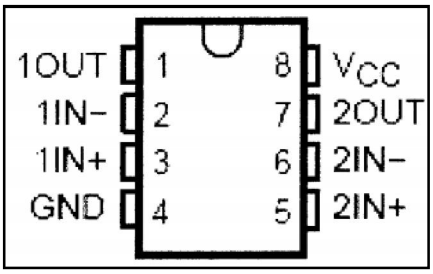

Figure 2.11: IC LM358 pin description

1. Wide supply range : single supply 3V to 32V
2. Dual supplies : 1.5V to 16V
3. Low supply-current drain, independent of supply voltage : 0.7mA Typ
4. Common-Mode input voltage range includes Ground, allowing direct sensing near Ground

5. Low input bias and offset parameters:
    - Input Offset Voltage : 3mV Typ
    - Input Offset Current : 2nA Typ
    - Input bias Current : 20nA Typ
6. Differential input voltage range equal to maximum-rated supply voltage : 32V
7. Open-loop differential voltage amplification : 100V/mV Typ
8. Internal frequency compensation.

CHAPTER 3

METHADOLOGY

3.1 Introduction

In this chapter will explain the stages related to production projects. Each stage is planned carefully for the development of the project runs smoothly until completion. However, there are some parts that are important in making a project and it should be emphasized.

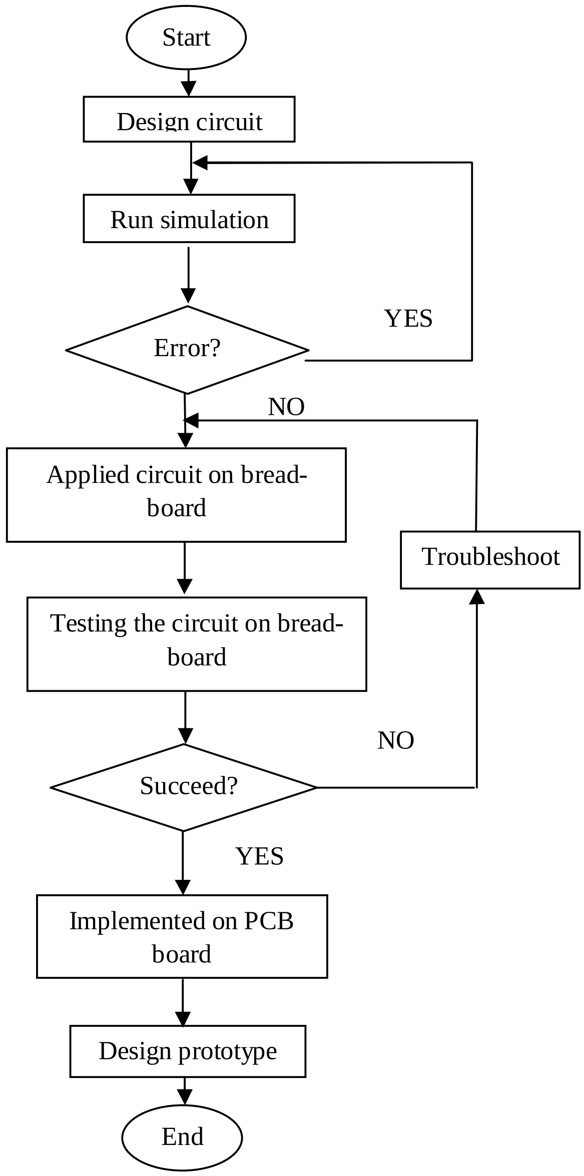

Figure 3.1: Flow chart of implementation planning

3.2 Software

Software development for this project can be divided into 2 parts which are for microcontroller and for circuit design

3.2.1 Design Circuit and Simulation

After the sensor that want to be use is have been decided, the suitable circuit are searched as reference to design the circuit using Multism 11. Figure 3.2.1 below is such a circuit that can be used to make the distance measurement detector device that based on the ultrasonic sensor and PIC microcontroller. The simulation of the circuit is compulsory to make sure the circuit runs completely without any problems. The simulation consider the output voltage, output frequency that generated by the PIC. The ultrasonic sensor is not available in this simulation program, and has been replaced by the oscilloscope and function generator. The function generator act to inject 40 kHz of frequency to the receiver part.

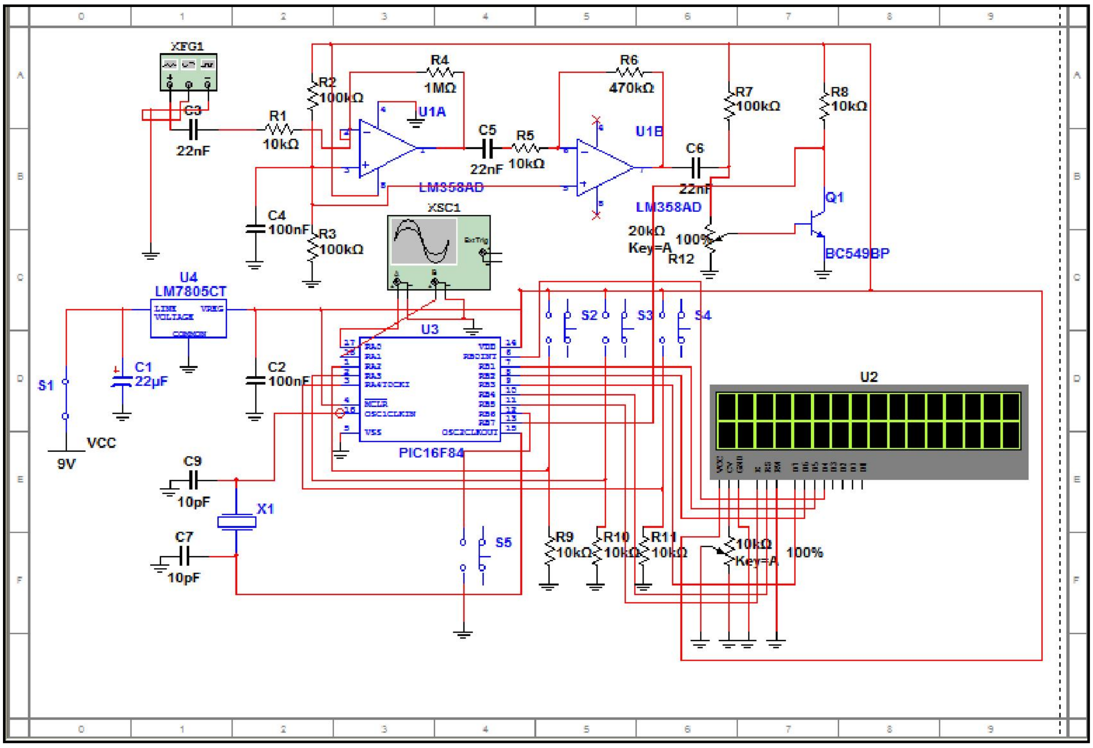

Figure 3.2: Circuit Drawing for Project

3.2.2 PIC programming

After successful build a source code by using Micro C Pro for PIC software, the last process to burning programming. The process will be continuous with USB Programmer. PIC kits must be needed to complete on this process.

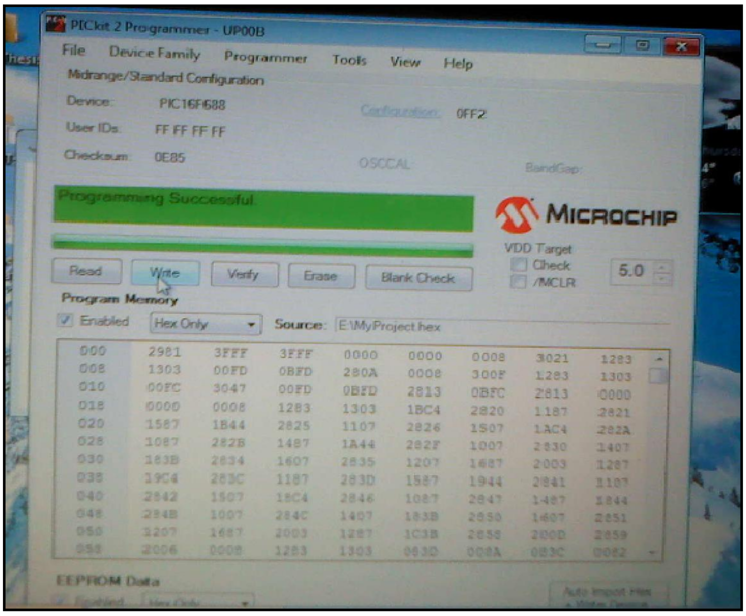

Figure 3.3: PICkit 2 programmer software

Figure 3.4: Position of PIC at USB Programmer

3.2.3 Printed Circuit Board (PCB)

Using the Eagle 5.1.0 software, the schematic circuit is drawn to get the layout of the circuit board as figure 3.6.1 and figure 3.6.2. After that, the circuit is mirrored to print-out on the real PCB before the drilling process can take part.

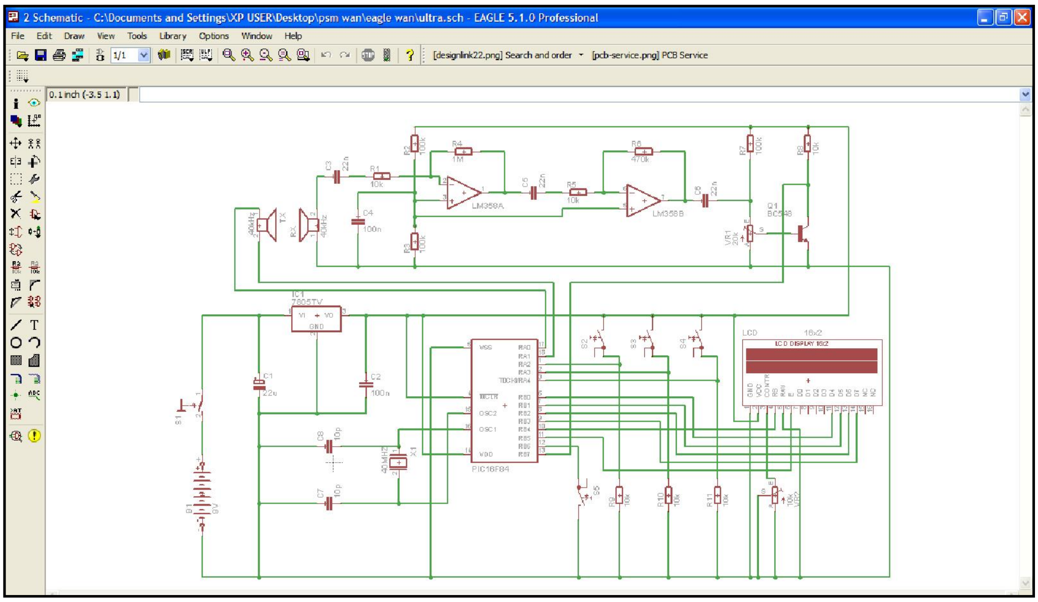

Figure 3.5: Schematic Using Eagle 5.1.0

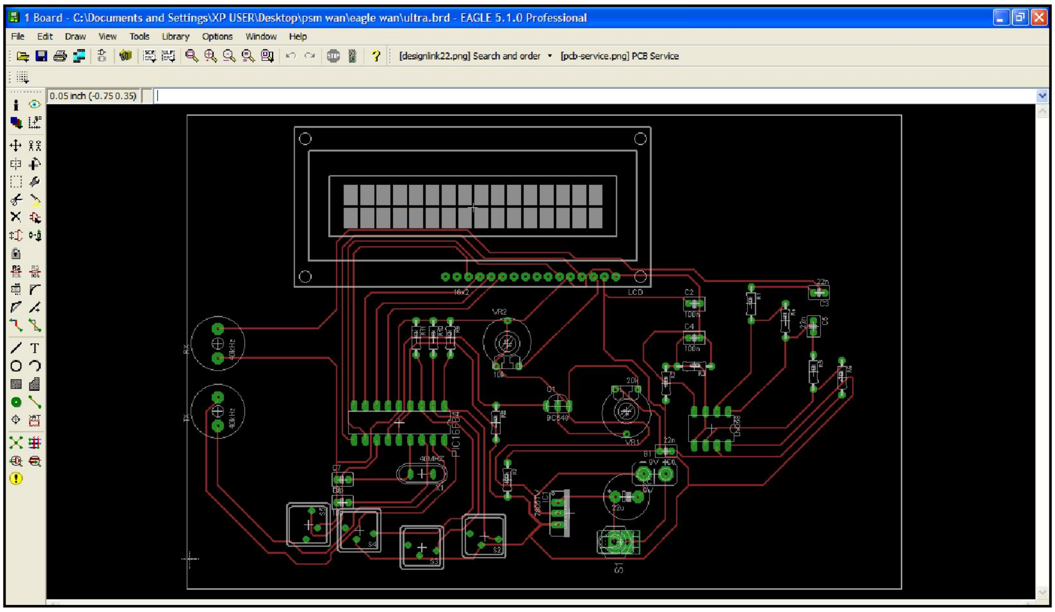

Figure 3.6: PCB Layout Using Eagle 5.1.0

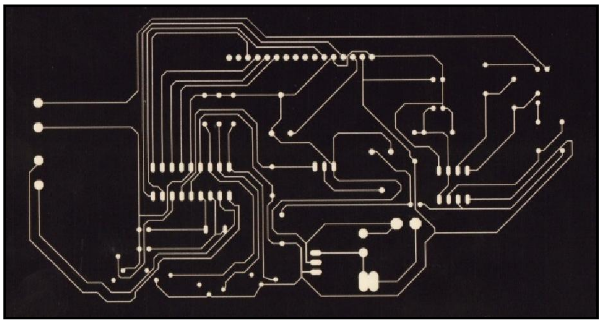

Figure 3.7: Circuit Layout to Print

3.3 Hardware

This part of the design has to be flexible and easy to adapt to new transducer configurations or other modifications of the measurement system. Because of this it should be built on a modular basis. A couple of common functions can easily be identified but their implementation may vary between different kind of sensors, sensor configurations or purposes of the measurements.

3.3.1 Transmitter / Receiver

Most transducer elements can be used as both receiver and transmitter. This is an advantage since the physical dimensions of the measurement unit are critical. Furthermore, the use of an arbitrary element as the transmitting one means that the "illumination" of the measurement area can be done from several different angles. This requires a transmitter/receiver selection function to be included. This function is not critical in a microsecond perspective but a switch between transmitter/receiver configurations should be able to take place between two measurements

3.3.2 Sampling and Data Storage

The data acquisition in the system requires special attention. It is important for the following signal processing that the signals are sampled simultaneously in all channels at periodic and precise time instants. This should be done by a unit for sampling and data storage. The sampling rate has to be sufficiently high to give a good representation of the highest frequency used. It should also be adjustable so that when measuring at lower frequencies the amount of data produced does not become unnecessarily large. Since the highest usable frequency for the current measurements is somewhere around 200 kHz and it is reasonable to sample about 10 times per period an appropriate sampling frequency would be in the region of 2 MHz.

3.4 Test on Training-Board

The next are to implement the circuit on real board. Before that, the circuit is tested on the board called training-board or bread board. This method is to analyze and to test the real application of the circuit based on the result from simulation and to check the compability of the components to use on the circuit project.

3.5 Design Prototype

The last step is to design the prototype of the project such as making the casing for the project to be as a real measuring device. The prototype that designed must be compact and tidy, suitable as a portable device. The casing made from transparent perspex is used to give the outlook of the board inside it.

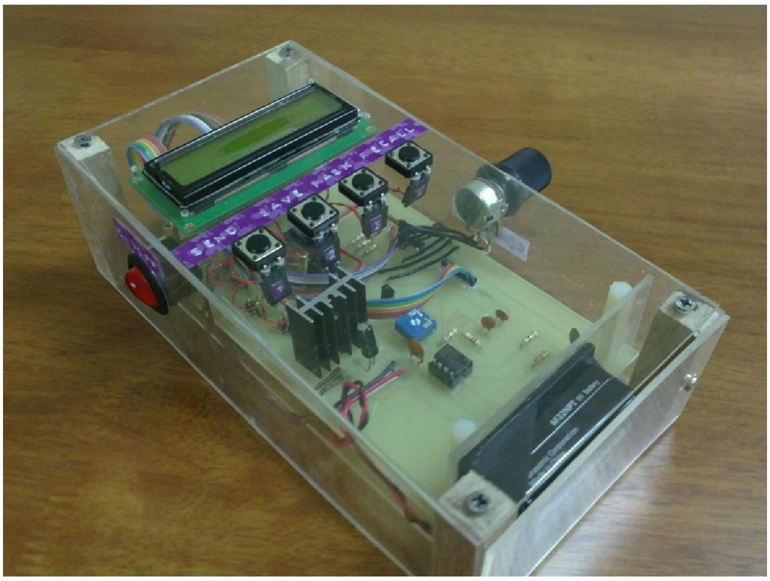

Figure 3.8: Project Prototype

Figure 3.9: Project Prototype from top view

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter discusses on the result and analysis data that are encountered throughout the completion of this project. After the development and completion of this project, it will be evaluated in order to measure the effectiveness and to ensure whether it had met the outlined objectives successfully. The results for this project are consists by two parts, which is software and hardware.

4.2 Software

Figure 4.2.1 shows the circuit using Multisim 11 software. This method used to check whether the PIC 16F84A can generated the impulse of 40 kHz to be transmitted through the ultrasonic transmitter before received on the receiver's part.

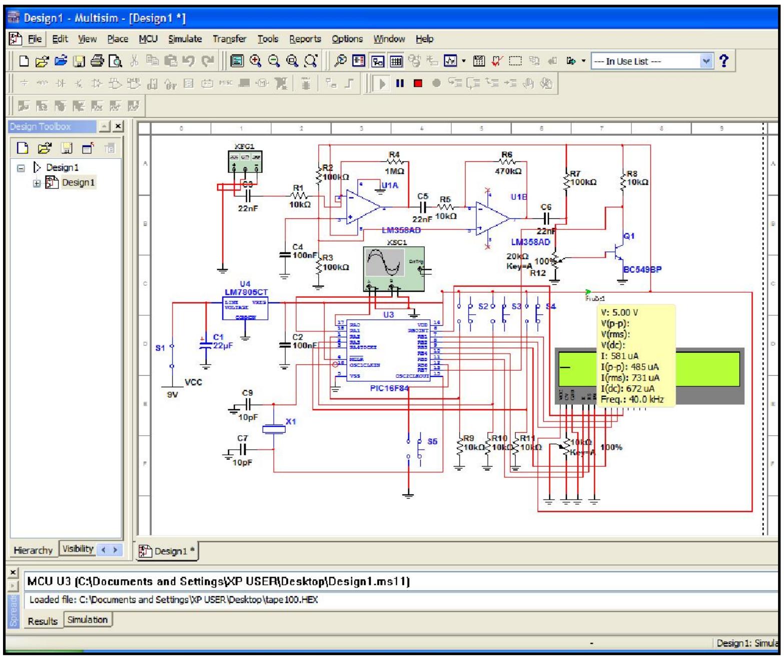

Figure 4.1: Simulation by using Multisim 11software

4.3 Circuit Application

4.3.1 Power Supply

The circuit runs from 9V PP3 battery. Current drawn is normally about 6mA, rising to about 7mA during transmission. Regulator IC3 drops the 9V supply down to 5V to suit the PIC and the LCD.

4.3.2 Amplification

The 40 kHz echo signals receive two stages of ac amplification. A gain of 100 is provided by op-amp IC1a, as set by resistors R1 and R4. Op-amp IC1b provides a further gain of about 47, as set by R5 and R6.

Capacitor C6 then feeds the amplified signal to transistor TR1, whose purpose is to provide logic-level pulses to the PIC at pin RB7. Between them, resistor R7 and preset VR1 set a basic dc bias on the base (b) of TR1, determining the response sensitivity.

The output from TR1's collector (c) normally rests at 5V, but swings between 5V and 0V in the presence of suitably strong echo signals. Immediately the PIC has finished transmitting the brief chain of 40 kHz pulses, it starts a 2-byte counter (16-bits) which increments at a known rate. When the PIC recognizes that pin RB7 has changed its logic state from high to low in response to an output from TR1, the counter is stopped.

4.3.3 Calculation

The software now goes into its calculation routine, in which it converts the count value into two distance values, one in metric (three decimal places) and one in imperial (feet and inches). These measurements are displayed on the X2 16-character 2-line

LCD. Meters are shown top left, followed by letters “mt”. Feet and inches are bottom lest, complete with letters of “ft” and “in”.

The transmission and echo conversion process continues for as long as the “Send” button remains pressed. At this moment, releasing the switch will cause the last measurement read to stay on the LCD screen. It will remain there until “Send” is pressed again, or “Recall” switch S5 is pressed, or the unit is switched off. While “Send” is pressed, the sampling rate is normally a little under once per second, depending on the mask and distance values.

4.3.4 Measurement Recording

The measurement shown on the display is not yet recorded in the PIC’s EEPROM memory. That action occurs when “Store” switch is pressed. Since the switch status is only read by the PIC when it has finished its calculation and display, the measurement recorded is always the one just completed. This ensures that an incomplete measurement is never stopped.

The information is stored as the count value achieved, nit in meters or feet. Consequently, only two bytes of EEPROM memory are used. The PIC has 64 bytes of this memory available and up to 32 measurements can be recorded with the standard program. With the extended program, 30 measurements can be stored, the other bytes being reserved for timing and counting values.

Each time a measurement is stored, a record counter is incremented. This is displayed on the top right of the LCD so that the total readings that have taken is known.

Immediately in front of this value, the message “Saved” appears. It is not possible to step the counter back in order to store another measurement at this count location. Thus, when the error in recording are made, the value at the location is to be disregarded when examine the recording later.

4.3.5 Playback

To play back the stored recordings, the “Recall” switch is used. Each time it is pressed, a Recall counter is incremented. The 2-bytes data from the EEPROM at the equivalent address to the count (count x 2) is read and converted to metric and imperial as before.

The Recall counter value is also displayed at the top right in the place of the Record counter value. Immediately in front of it, the message “SHOW=” appears.

4.3.6 EEPROM Reset

A facility to reset the Record and Recall counters to zero during normal use has not been included. The Recall counter is reset at each switch on, but the Record counter is only reset when the full EEPROM measurement data contents are reset. The data EEPROM measurement data remains intact until intentionally reset. This can be done at switch on. if the Store button is pressed and held down immediately prior to and during switching on, all stored measurements are cleared, and the Record and Recall counters set to zero.

4.3.7 Masking

The masking facility allows foreground echoes to be ignored within a timing or distance range set via “Mask” switch S4. This allows for example, to read the distance of a far wall when a clutter of furniture is between the devices and wall. Without this facility, the echoes from the furniture would those read by the distance measurement device.

4.4 Measuring the Distance

4.4.1 Flat Surface

An angular measurement is based on the fact that if an ultrasonic wave is sent towards a flat surface it is reflected in a specular reflection i.e. the angle of incidence equals the angle of reflection. This means that we can look upon the reflecting surface as a mirror. The transmitter lobe can be modeled as a number of beams of various intensities. In this model the beam that will hit the receiver can be constructed by searching for a reflection point that satisfies the law of specular reflection. The beam found in this way also describes the shortest path from transmitter to receiver via the surface. Because of this there can’t be any problem introduced by diffraction causing a new wave front that arrives earlier.

Consequently, a configuration as the one shown in Figure 4.4.1.1 with one transmitting element and two receiving ones can be used to measure the inclination of a surface. By measuring the time from transmission of a pulse to reception at transducers a and b the distance r_0 and the angle α can be calculated.

If the phase angle between signals from two transducers are measured when the sensor plane is in parallel with a base plane surface a calibration value can be stored. Using this value small deviation can be measured with high accuracy since the phase angle difference is easily detected. In a pulsed system this phase difference may cover several cycles of the signal. The measurement can, however, also be made with a continuous wave (CW) ultrasonic signal.

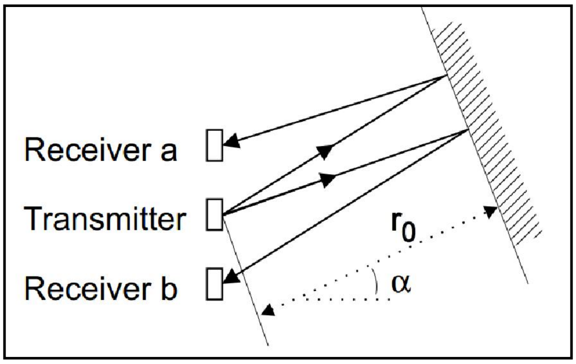

Figure 4.2: Reflection of the Ultrasonic wave

Before the detailed description of the measurements it is important to note that angular measurements are dependent on two major restrictions:

- The surface must have a measurement area that is large enough to reflect the beams indicated in Figure 4.4.1.1 above. Consequently it has to measure at least half the distance between the receivers. Furthermore, this minimum measure will only be sufficient provided that the object is placed exactly in the correct position.

- The measurement area must be within the transmitter lobe angle so that both beam reflection points are sufficiently "illuminated" by the transmitter

.

These restrictions might seem a bit limiting at the first glance but will usually not cause any trouble. The usable lobe of transducer can often be approximated with expression (4.5). This means that for most elements in the 40-60 kHz band the lobe is about 30-50°. In the case of large signal amplitudes, significantly larger angles can be used. In the sensor units, the distance between the sensors is less than 85 mm between the diagonal elements. This requires a surface with 43 mm diameter. If this is a too large dimension for the measurement task a sensor configuration with the elements located more closely is possible.

The simplest configuration to analyze is the two-dimensional case with symmetric receiver locations. In this case we assume that the receivers are placed at a distance of d/2 on each side of the transmitter.

4.5 Experimental Results

The range over which measurements have been done has not been extended to more than 5 meters. Consequently, the accuracy of the used distance measurement methods has primarily been tested for shorter distances.

However, most of the used methods may also be applied in scenarios where longer distances are of interest. The accuracy of all distance measurements depends a lot on the shape of the reflecting surface. Objects with surfaces that are small and not perpendicular to the acoustic axis can be almost impossible to detect. This gives no information about the possibilities of the methods. Because of this the described accuracy refers, when nothing else is stated, to measurements towards flat surfaces, perpendicular to the acoustic axis, and of sufficient size to produce a satisfactory signal.

4.6 Discussion

Ultrasound is usually defined as all sound with a frequency above 20 kHz. The only practical reason for this limit is that ultrasound then becomes equal to sound with a frequency too high for humans to hear. If we consider the physical behavior of sound with various frequencies there is no natural sharp limit. Some parameters are continuously affected when the frequency is changed while many stay the same. This means that much of the theory that is valid for audible sound can also be used for ultrasound.

For all the theory that will be presented it is crucial to assume that the medium for the ultrasonic waves should not be changed after that the wave has passed it. A major condition for this to be true is that the amplitude of the wave is sufficiently low.

4.6.1 The Speed of Sound

Sound propagates in free gases and liquids (without bounding surfaces) primarily as a longitudinal wave. For a wave that propagates in the direction of the x-axis the wave equation can be written as equation (4.1).

$$\frac{\partial^2 \xi}{\partial t^2} = c^2 \cdot \frac{\partial^2 \xi}{\partial x^2} \qquad (4.1)$$

Where:

ξ = particle displacement
t = the time
c = propagation velocity

From that expression and what is known about the relations between pressure, density, volume and temperature in gases it is possible to give an expression for the propagation velocity in a gas.

$$c = \sqrt{\frac{\gamma \cdot P}{\rho}} = \sqrt{\frac{\gamma \cdot R \cdot T}{M}} \qquad (4.2)$$

Where:

γ = ratio between the specific heat at constant pressure

(cp /cv)= constant volume

P = pressure

ρ = the density

R = universal gas constant

T = absolute temperature

M = molecular weight.

From the first part of expression (4.2) it is possible to calculate an approximate numeric value for the velocity of sound in air. At normal atmospheric pressure and a temperature of 0 °C (ρ depends on the temperature) the velocity is about 331 m/s.

From the second part of expression (4.2) it is obvious that the velocity is proportional to the square root of the absolute temperature as (4.3)

$$c \sim \sqrt{T} \tag{4.3}$$

From this correspondence we get an expression that makes it possible to compensate for a temperature deviation when the velocity is known at a specific temperature T_0.

$$c_1 = c_0 \cdot \sqrt{1 + \frac{T_1 - T_0}{T_0}} \tag{4.4}$$

Where:

c_0 and c_1 = velocities at T_0 and T_1 respectively.

From (4.4) it is found that the sensitivity at 0 °C is about 0.6 m/s / °C .When the speed of sound in air is to be measured there is another problem than the temperature. Air is actually a mixture of gases. The primary components are, of course, oxygen and nitrogen. In practice the air also consists of various concentrations of water vapor and carbon dioxide. These concentrations affect the velocity. The influence of this is, however, usually not large compared to the influence of temperature changes. Nevertheless, it is important to keep these effects in mind when measurements are made in environments where large concentrations of other gases are present.

4.6.2 Wave Models

A sound-wave also has to be defined by its shape (wave-front propagation). There are two types of waves that are easy to handle and therefore often referred to. The first one is the plane parallel wave, Figure 4.1. In this case the wave front moves like a geometric plane in a direction perpendicular to the plane. The pressure in all points in an arbitrary plane parallel with, but behind, this one is uniform.

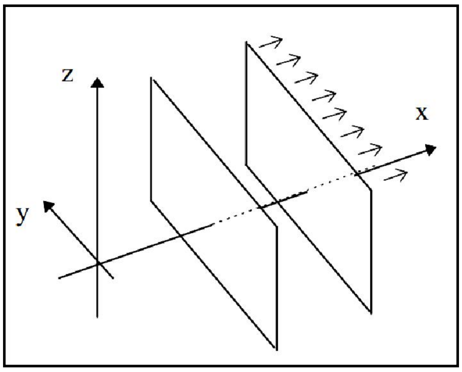

Figure 4.3 : Plane parallel wave model

The second one is the spherical wave, Figure 4.2. In this case the origin of the wave is assumed to be a point source transmitting in all directions. The pressure in an arbitrary sphere is of course uniform but there is a major difference compared to the plane wave. The pressure amplitude decreases with the distance to the source.

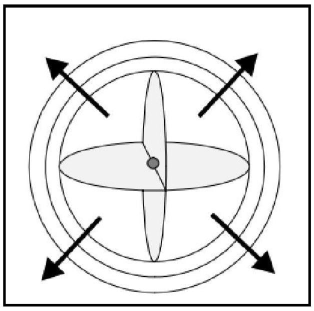

Figure 4.4 : Spherical waves from a point source

Usually neither of these two models is appropriate for practical ultrasonic sources. A transmitter can usually be replaced with a number of point sources if the wave is studied from within a bounded area. Another common way of finding an equivalent source is to use the model of a plane parallel wave, with the wavelength λ, that passes through a circular opening with the diameter D in an infinite baffle, called the piston model. The intensity in this lobe reaches it first minimum, at the angle θ_0 where:

$$\sin(\theta_0) = 1.22 \cdot \frac{\lambda}{D} \tag{4.5}$$

4.6.3 Frequencies

There is no absolute upper limit defined for the frequency of ultrasonic. Two practical reasons, however, limit the frequency range that can be used for measurements in air. Primarily the attenuation per meter is higher at higher frequencies. This is no major problem for frequencies below about 100 kHz. As a rule of thumb the amplitude is decreased to 50 % after about 2 meters at 100 kHz. This assumes a plane wave. For frequencies in the MHz-region, however, the attenuation problem becomes highly significant.

Secondarily the lobe is much narrower at higher frequencies according to (4.5), since the wavelength is decreased. The effective diameter of transducers for higher frequencies is generally often smaller than for low frequencies. This makes the lobe beam-like. As a consequence only one point of a reflecting object is “illuminated” by the beam. Following the law of reflection the angle of reflection is equal to the angle of incidence and an echo from the object is only produced in one direction.

The frequency that is chosen for a measurement has a large influence of the accuracy that can be achieved. Since the wavelength in air at 20 kHz is about 17 mm a higher frequency might be preferred for precision measurements. It should be noted, however, that the resolution for distance measurement using the pulse echo method is not limited to the magnitude of the wavelength. A sophisticated method for finding the beginning of the echo-pulse may give a resolution and an accuracy within fractions of a wavelength.

It is very difficult to make categorical statements about the amount of noise and disturbances at different frequencies since various sources may produce undesired signals at quite different frequency ranges. A measurement in every special application may therefore be needed. In general the amount of disturbances and noise is lower at higher frequencies, due to the higher damping for higher frequencies.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Ultrasonic sensors use sound instead of light for ranging, so ultrasonic sensors can be used outside in bright sunlight. These sensors are amazingly accurate, though they may be thrown off by a sound absorbing obstacle, like a sponge. The **ultrasonic sensor** produces a data carrier utilizing very high frequencies that are outside the human's audible range. The time it takes for that ultrasonic wave to pass between the sensor and the object is the value for the distance or the position.

The only real issue that arises is the "ghost echo" issue. The amplitude of the wave reflected is directly proportional to how much surface is available on the object for coherent reflection. Surface size, shape and orientation, are major factors contributing to the strength of the reflected signal; material composition is also a factor. A part of the wave landing on the surface of the material is reflected, while a part of the wave penetrates the material and is eventually reflected of any surface boundaries encountered while travelling within the material.

But in the end, the project has been successfully done and it is working according to its needs. Nevertheless, there are still some parts in the system needed to be improved in future so that a more reliable system can be achieved.

5.2 Recommendation

i. To improve the measuring system, so the ultrasonic can measured far distance than existed.
ii. Add more functions in the measuring device to make this project very interesting and more advanced.

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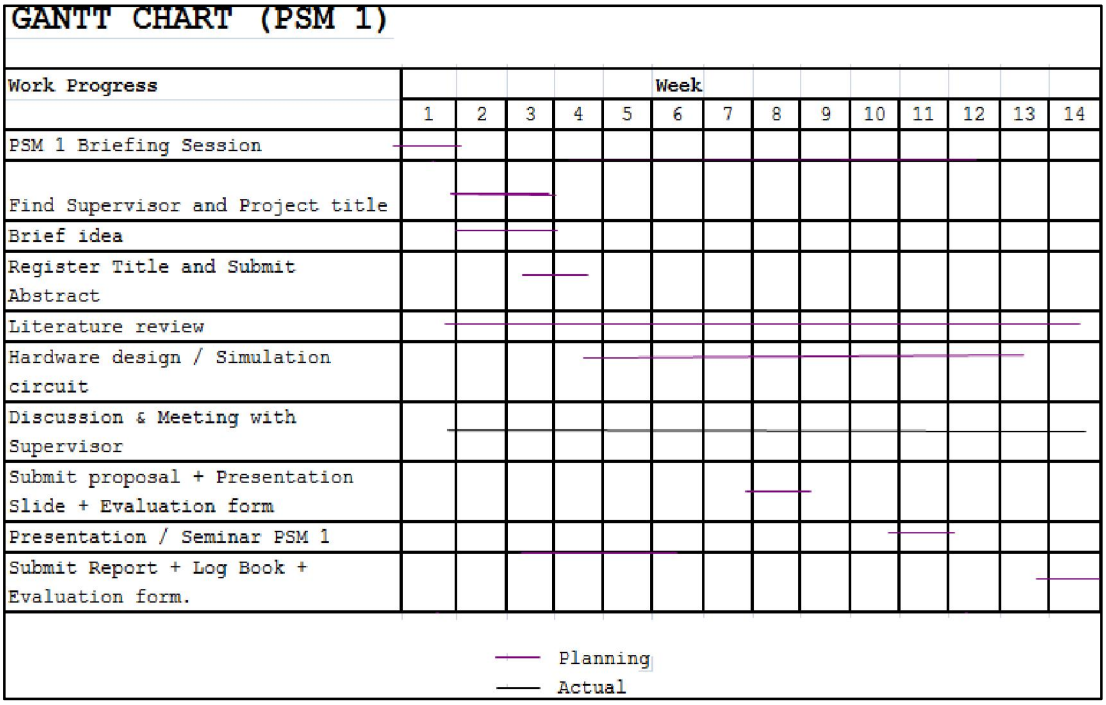
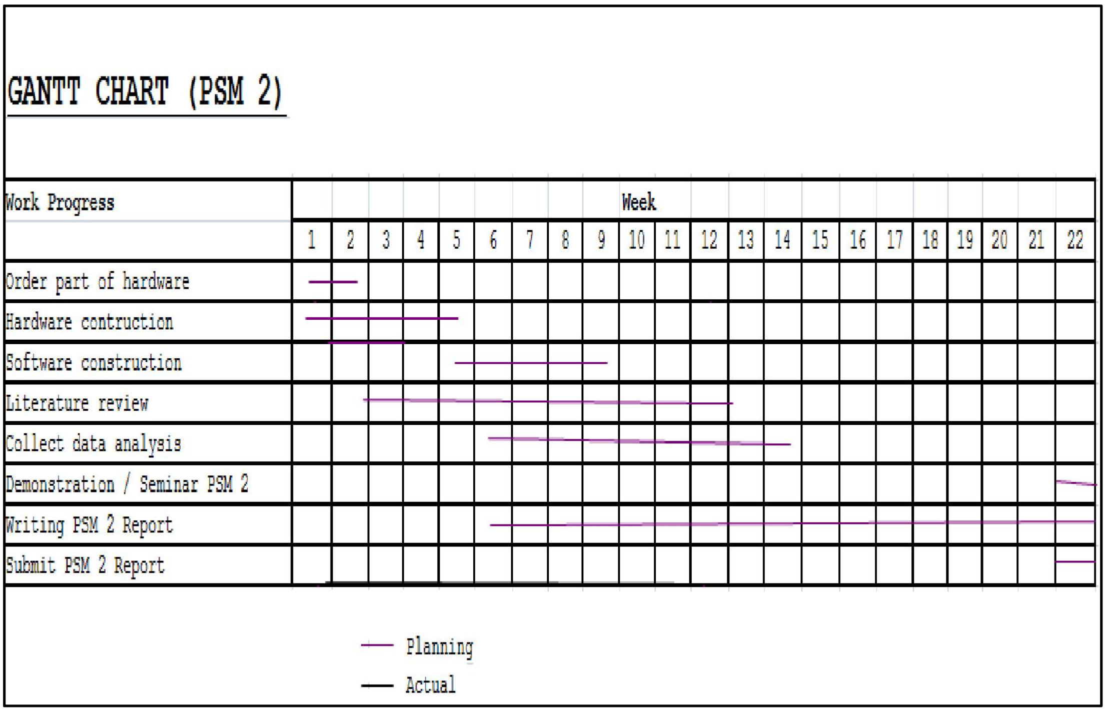
APPENDICES

APPENDIX A

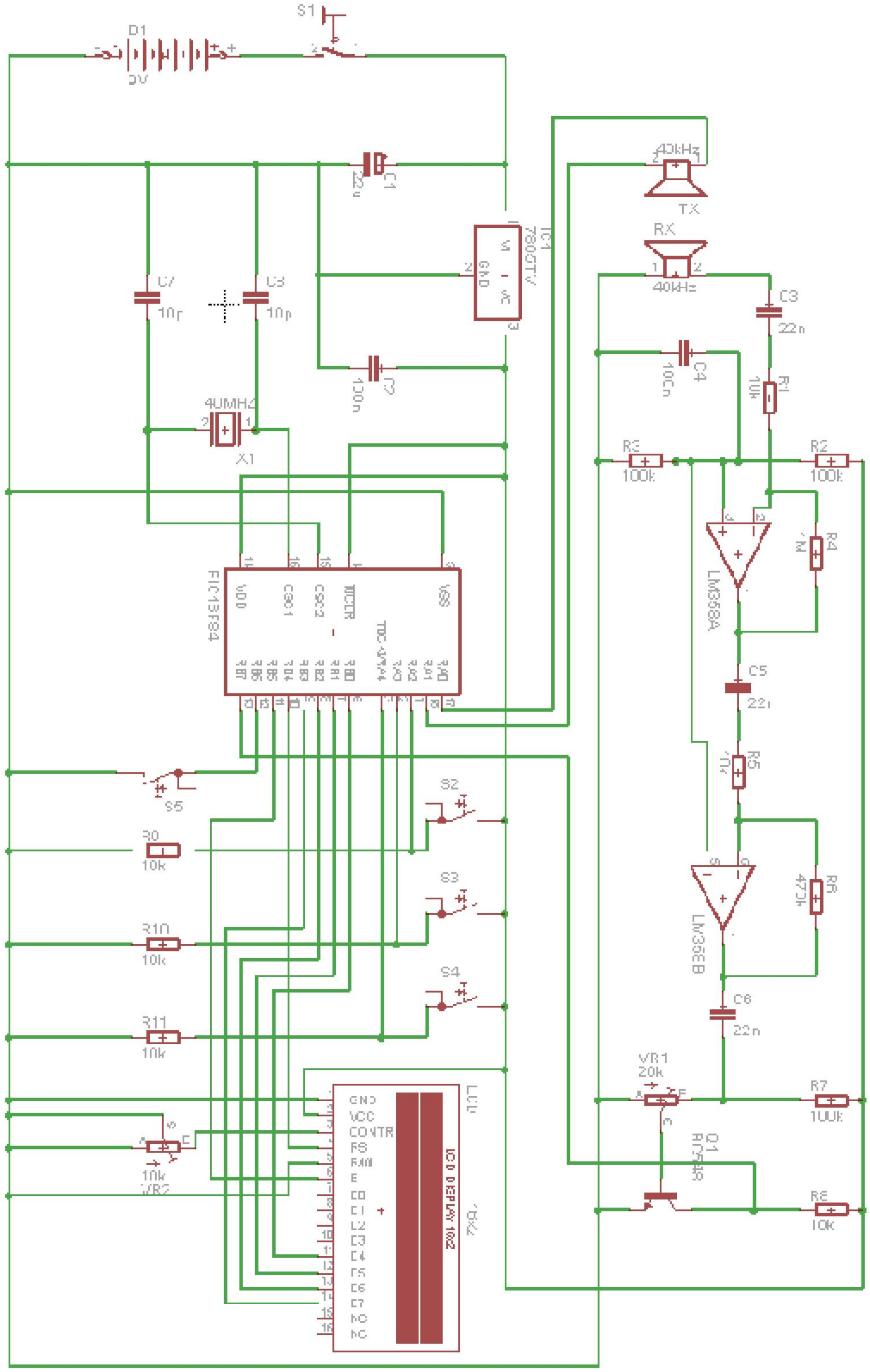
(Gantt Chart PSM 1 and PSM 2)





APPENDIX B

(Full Circuit)



APPENDIX C

(PIC16F84A Datasheet)

MICROCHIP

PIC16C8X

8-Bit CMOS EEPROM Microcontrollers

Devices Included in this Data Sheet:

- PIC16C83
- PIC16CR83
- PIC16C84
- PIC16C84A
- PIC16CR84
- Extended voltage range devices available (PIC16LC8X)

High Performance RISC CPU Features

- Only 35 single word instructions to learn
- All instructions single cycle (400 ns @ 10 MHz) except for program branches which are two-cycle
- Operating speed: DC - 10 MHz clock input
  DC - 400 ns instruction cycle

Device	Memory			Freq Max.
	Program	Data RAM	Data EEPROM	
PIC16C83	512 words	36	64	10 MHz
PIC16CR83	512 words†	36	64	10 MHz
PIC16C84	1 K words	36	64	10 MHz
PIC16C84A	1 K words	68	64	10 MHz
PIC16CR84	1 K words†	68	64	10 MHz

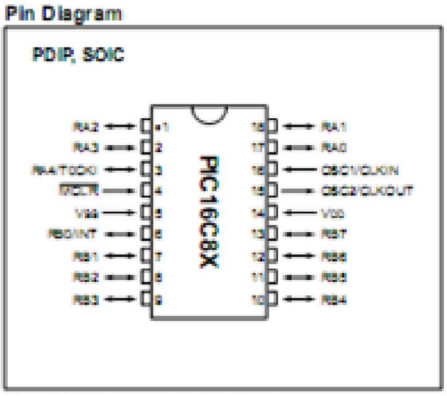
† ROM Program Memory Devices

- 14-bit wide instructions
- 8-bit wide data path
- 15 special function hardware registers
- Eight-level deep hardware stack
- Direct, indirect and relative addressing modes
- Four interrupt sources:
  - External RB0/INT pin
  - TMR0 timer overflow
  - PORTB<7:4> interrupt on change
  - Data EEPROM write complete
- 1,000,000 data memory EEPROM ERASE/WRITE cycles - Typical
- EEPROM Data Retention > 40 years

Peripheral Features

- 13 I/O pins with individual direction control
- High current sink/source for direct LED drive
  - 25 mA sink max. per pin
  - 20 mA source max. per pin
- TMR0: 8-bit timer/counter with 8-bit programmable prescaler

Pin Diagram



Special Microcontroller Features

- Power-on Reset (POR)
- Power-up Timer (PWRT)
- Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Serial In-System Programming - via two pins (ROM devices support only Data EEPROM programming)

CMOS Technology

- Low-power, high-speed CMOS EEPROM technology
- Fully static design
- Wide operating voltage range:
  - Commercial: 2.0V to 6.0V
  - Industrial: 2.0V to 6.0V
- Low power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 15 μA typical @ 2V, 32 kHz
  - < 1 μA typical standby current @ 2V (all devices except PIC16C84)

(PIC16F84A Datasheet)

PIC16C8X

Applicable Devices	83	R83	84	84A	R84

TABLE 13-1: CROSS REFERENCE OF DEVICE SPECS FOR OSCILLATOR CONFIGURATIONS AND FREQUENCIES OF OPERATION (COMMERCIAL DEVICES)

OSC	PIC16C84A-04 PIC16CR84-04 PIC16C83-04 PIC16CR83-04	PIC16C84A-10 PIC16CR84-10 PIC16C83-10 PIC16CR83-10	PIC16LC84A-04 PIC16LCR84-94 PIC16LC83-04 PIC16LCR83-04
RC	V_{DD}: 4.0V to 6.0V I_{DD}: 4.5 mA max. at 5.5V I_{PD}: 14 µA max. at 4V WDT dis Freq: 4.0 MHz max.	V_{DD}: 4.5V to 5.5V I_{DD}: 1.8 mA typ. at 5.5V I_{PD}: 1.0 µA typ at 5.5V WDT dis Freq: 4..0 MHz max.	V_{DD}: 2.0V to 6.0V I_{DD}: 4.5 mA max. at 5.5V I_{PD}: 7.0 µA max at 2V WDT dis Freq: 2.0 MHz max.
XT	V_{DD}: 4.0V to 6.0V I_{DD}: 4.5 mA max. at 5.5V I_{PD}: 14 µA max. at 4V WDT dis Freq: 4.0 MHz max.	V_{DD}: 4.5V to 5.5V I_{DD}: 1.8 mA typ. at 5.5V I_{PD}: 1.0 µA typ at 5.5V WDT dis Freq: 4.0 MHz max.	V_{DD}: 2.0V to 6.0V I_{DD}: 4.5 mA max. at 5.5V I_{PD}: 7.0 µA max at 2V WDT dis Freq: 2.0 MHz max.
HS	V_{DD}: 4.5V to 5.5V I_{DD}: 4.5 mA typ. at 5.5V I_{PD}: 1.0 µA typ. at 4.5V WDT dis Freq: 4.0 MHz max.	V_{DD}: 4.5V to 5.5V I_{DD}: 10 mA max at 5.5V typ. I_{PD}: 1.0 µA typ at 4.5V WDT dis Freq: 10 MHz max.	Do not use in HS mode
LP	V_{DD}: 4.0V to 6.0V I_{DD}: 35 µA typ. at 32 kHz, 3.0V I_{PD}: 0.6 µA typ. at 3.0V WDT dis Freq: 200 kHz max.	Do not use in LP mode	V_{DD}: 2.0V to 6.0V I_{DD}: 32 µA max at 32 kHz, 3.0V I_{PD}: 7 µA max at 2.0V WDT dis Freq: 200 kHz max.

The shaded sections indicate oscillator selections which are tested for functionality, but not for MIN/MAX specifications. It is recommended that the user select the device type that ensures the specifications required.

APPENDIX D

(LM358 Datasheet)

LM158,A-LM258,A
LM358,A

LOW POWER DUAL OPERATIONAL AMPLIFIERS

- INTERNALLY FREQUENCY COMPENSATED
- LARGE DC VOLTAGE GAIN: 100dB
- WIDE BANDWIDTH (unity gain): 1.1MHz (temperature compensated)
- VERY LOW SUPPLY CURRENT/OP (500µA) ESSENTIALLY INDEPENDENT OF SUPPLY VOLTAGE
- LOW INPUT BIAS CURRENT: 20nA (temperature compensated)
- LOW INPUT OFFSET VOLTAGE: 2mV
- LOW INPUT OFFSET CURRENT: 2nA
- INPUT COMMON-MODE VOLTAGE RANGE INCLUDES GROUND
- DIFFERENTIAL INPUT VOLTAGE RANGE EQUAL TO THE POWER SUPPLY VOLTAGE
- LARGE OUTPUT VOLTAGE SWING 0V TO (Vcc - 1.5V)

N
DIP8
(Plastic Package)

D & S
SO8 & miniSO8
(Plastic Micropackage)

P
TSSOP8
(Thin Shrink Small Outline Package)

DESCRIPTION

These circuits consist of two independent, high gain, internally frequency compensated which were designed specifically to operate from a single power supply over a wide range of voltages. The low power supply drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, dc gain blocks and all the conventional op-amp circuits which now can be more easily implemented in single power supply systems. For example, these circuits can be directly supplied with the standard +5V which is used in logic systems and will easily provide the required interface electronics without requiring any additional power supply.

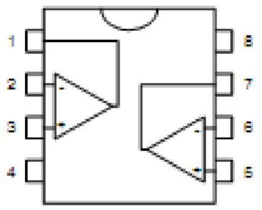
In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage.

ORDER CODE

Part Number	Temperature Range	Package			
		N	S	D	P
LM158,A	-55°C, +125°C	•		•	•
LM258,A	-40°C, +105°C	•		•	•
LM358,A	0°C, +70°C	•	•	•	•
Example : LM258N					

N = Dual in Line Package (DIP)
D = Small Outline Package (SO) - also available in Tape & Reel (DT)
S = Small Outline Package (miniSO) only available in Tape & Reel (DT)
P = Thin Shrink Small Outline Package (TSSOP) - only available in Tape & Reel (PT)

PIN CONNECTIONS (top view)



1 - Output 1
2 - Inverting input
3 - Non-inverting input
4 - V_{CC}^-
5 - Non-inverting input 2
6 - Inverting input 2
7 - Output 2
8 - V_{CC}^+

January 2002 1/12

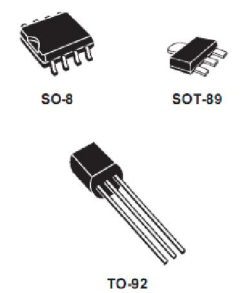
APPENDIX E

(LM7805 Datasheet)

L78L00 SERIES

POSITIVE VOLTAGE REGULATORS

- OUTPUT CURRENT UP TO 100 mA
- OUTPUT VOLTAGES OF 3.3; 5; 6; 8; 9; 12; 15; 18; 24V
- THERMAL OVERLOAD PROTECTION
- SHORT CIRCUIT PROTECTION
- NO EXTERNAL COMPONENTS ARE REQUIRED
- AVAILABLE IN EITHER ± 5% (AC) OR ± 10% (C) SELECTION



DESCRIPTION

The L78L00 series of three-terminal positive regulators employ internal current limiting and thermal shutdown, making them essentially indestructible. If adequate heatsink is provided, they can deliver up to 100 mA output current. They are intended as fixed voltage regulators in a wide range of applications including local or on-card regulation for elimination of noise and distribution problems associated with single-point regulation. In addition, they can be used with power pass elements to make high-current voltage regulators.

The L78L00 series used as Zener diode/resistor combination replacement, offers an effective output impedance improvement of typically two orders of magnetude, along with lower quiescent current and lower noise.

ABSOLUTE MAXIMUM RATING

Symbol	Parameter		Value	Unit
V_i	DC Input Voltage	V_o = 3.3 V to 9 V	30	V
		V_o = 12 V to 15 V	35	V
		V_o = 18 V to 24 V	40	V
I_o	Output Current		100	mA
P_{tot}	Power Dissipation		Internally limited (*)	
T_{stg}	Storage Temperature Range		- 40 to 150	°C
T_{op}	Operating Junction Temperature RangeFor L78L00C, L78L00AC For L78L00AB		0 to 125 - 40 to 125	°C °C

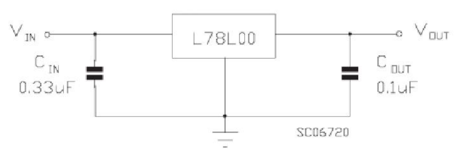
(*) Our SO-8 package used for Voltage Regulators is modified internally to have pins 2, 3, 6 and 7 electrically commoned to the die attach flag. This particular frame decreases the total thermal resistance of the package and increases its ability to dissipate power when an appropriate area of copper on the printed circuit board is available for heatsinking. The external dimensions are the same as for the standard SO-8

THERMAL DATA

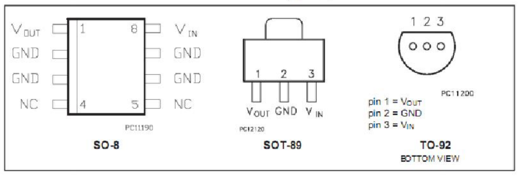
Symbol	Parameter		SO-8	TO-92	SOT-89	Unit
$R_{thj-case}$	Thermal Resistance Junction-case	Max	20		15	°C/W
$R_{thj-amb}$	Thermal Resistance Junction-ambient	Max	55 (*)	200		°C/W

(*) Considering 6cm² of copper Board heat-sink

TEST CIRCUITS



CONNECTION DIAGRAM AND ORDERING NUMBERS (top view)



APPENDIX F

(Liquid Crystal Display (LCD) Datasheet)

AC1602A (16 CHARACTERS x2 LINES)

FEATURES

- 5 x 7 DOTS WITH CURSOR
- BUILT-IN CONTROLLER (KS0066 OR EQUIVALENT)
- 5 V POWER SUPPLY
- 1/16 DUTY CYCLE
- 4.2 V LED FORWARD VOLTAGE

MECHANICAL DATA

ITEM	DIMENSIONS	UNIT
Module Size (W x H x T)	80 x 36 x 8.8 (12.7 LED)	mm
Viewing Area (W x H)	65.0 x 16.0	mm
Character Size (W x H)	2.96 x 5.56	mm
Character Pitch (W x H)	3.55 x 5.94	mm
Dot Size (W x H)	0.56 x 0.66	mm
Dot Pitch (W x H)	0.60 x 0.70	mm

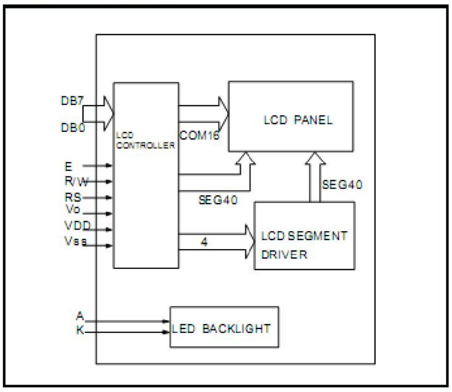
INTERFACE PIN CONNECTIONS

NO.	SYMBOL	FUNCTION	NO.	SYMBOL	FUNCTION
1	Vss	0V	9	DB2	Data Bit 2
2	VDD	5V	10	DB3	Data Bit 3
3	Vo	Contrast Adj.	11	DB4	Data Bit 4
4	RS	Register Select	12	DB5	Data Bit 5
5	R/W	Read/Write	13	DB6	Data Bit 6
6	E	Enable Signal	14	DB7	Data Bit 7
7	DB0	Data Bit 0	15	A	LED Power
8	DB1	Data Bit 1	16	K	LED Power

ELECTRICAL CHARACTERISTICS

ITEM		SYMBOL	CONDITION	MIN.	TYP.	MAX.	UNIT
LCD Operating Voltage		VDD-Vo	T=0 °C	-	4.8	-	V
			T=25 °C	-	4.5	-	V
			T=50 °C	-	4.2	-	V
Supply Voltage		VDD-Vss	-	4.7	5	5.3	V
Supply Current		IDD	-	-	2	4	mA
Input Voltage	"HIGH" Level	VIH	-	2.2	-	VDD	V
	"LOW" Level	VIL	-	0	-	0.6	V
Output Voltage	"HIGH" Level	VOH	-	2.4	-	-	V
	"LOW" Level	VOL	-	-	-	0.4	V

BLOCK DIAGRAM



EXTERNAL DIMENSIONS