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JUDUL: **DEVELOPMENT OF SINGLE STATION LIGHTNING
DETECTION SYSTEM**

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DEVELOPMENT OF SINGLE STATION LIGHTNING DETECTION SYSTEM

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This thesis is submitted as partial fulfillment of the requirements for the award of the
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ABSTRACT

The lightning strikes billion of times, kill many of people, and damages billion of assets per year. This problem may be properly managed by using a lightning detection system. In this project, the lightning detector circuit was designed by using PIC16F877A microcontroller. The purposes of this project are to determine the distance and direction of lightning strikes. One wire antenna and a pair of loop antenna were attached to the circuit. A pair of loop antennas is used to sense the magnetic field produce by the lightning strike and a wire antenna is used to sense the electric field produce by the lightning strike. Three variable resistor will act as the antenna in this project to give the variety input to the PIC microcontroller. CCS compiler is a software used to write the program to microcontroller. The program written for Graphic User Interface (GUI) is done by using Microsoft Visual Basic 6.0. LED will blink and LCD will display the data of distance and direction of lightning strike. Meanwhile, GUI will display the results also with the add on of electric field and magnetic field values of each antenna and save all the data in a laptop.

ABSTRAK

Kilat menyerang bilion kali, membunuh ramai orang, dan merosakkan bilion aset setahun. Masalah ini boleh diatasi dengan menggunakan sistem pengesanan kilat. Dalam projek ini, litar pengesan kilat telah direka dengan menggunakan mikropengawal PIC 16F877A. Tujuan projek ini adalah untuk menentukan jarak dan arah kilat berlaku. Satu wayar antena dan sepasang antena gelung telah dilampirkan kepada litar. Antena gelung digunakan untuk mengesan hasil medan magnet oleh kilat dan antena wayar digunakan untuk mengesan medan elektrik yang dihasilkan oleh kilat. Tiga perintang boleh ubah akan bertindak sebagai antena dalam projek ini untuk memberi pelbagai input kepada PIC. CCS pengkompil adalah perisian yang digunakan untuk menulis program untuk mikropengawal. Program yang ditulis untuk Antara Muka Pengguna Grafik (GUI) dilakukan dengan menggunakan Microsoft Visual Basic 6.0. LED akan berkelip dan LCD akan memaparkan data jarak dan arah kilat. Sementara itu, GUI juga akan memaparkan keputusan dengan penambahan nilai medan elektrik dan medan magnet pada setiap antena dan menyimpan semua data di dalam komputer riba.

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LIST OF ABBREVIATIONS

LCD	-	Liquid Crystal Display
VB	-	Visual Basic
GUI	-	Graphic User Interface
CCS	-	Custom Computer Services
A/D	-	Analog to digital
PIC	-	Programmable Interface Controller
MCLR	-	Master clear
IDE	-	Integrated Development Environment
HEX	-	Hexadecimal
OSC	-	Oscillator
USB	-	Universal Serial Bus
UART	-	Universal Asynchronous Receiver/Transmitter
I/O	-	Input and output
LED	-	Light-emitting diodes
TOA	-	Time of Arrival
TX	-	Transmitter
RX	-	Receiver
EF	-	Electric Field
MF1	-	Magnetic Field for Loop 1
MF2	-	Magnetic Field for Loop 2

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CHAPTER 1

INTRODUCTION

1.1 Overview

Lightning is the one of the most unpredictable forces of nature. Any lightning strike is initializing with the polarization of positive and negative charges within a storm cloud. Subsequently, the polarization generates electric field surrounding the cloud. When the electric field generated is strong enough, it will ionize and make the air become conductive. With the conductive air, [1] charges in the cloud can be transfer to the ground and hence lightning strike occur.

The lightning discharges radiate electromagnetic pulses in a wide frequency range from a few Hz up to several hundreds of MHz. Particularly the intense pulses appearing at very-low-frequency (VLF) are called VLF sferics, which has been used to remotely detect the location of lightning strike occur. The lightning location such as the information of distance and direction of lightning strike has been performed by multi-station or single-station technique.

Multi-station techniques are the most accurate to detect the location of strike of lightning which is combining the magnetic direction finding and time-of-arrival measurements of sferics, as demonstrated by the U.S national lightning detection network (NLDN) [2]. In 1996, (NLDN) uses 106 sensors that located over the continental United States to achieve the accuracy of 0.5 km [3].

The single-station techniques use a single VLF receiver and give a more convenient way to locate the sources [2]. The direction finding will combine with estimation of the distance to the source. The earliest researches, they use the apparatus that includes a first loop antenna system for sensing the magnetic field produced by the lightning which signal is filtered, square rooted, and fed into peak voltage holding circuit [4]. A second antenna is provided for sensing electric field produced by the lightning which is fed into filter, an absolute value meter, and to a peak voltage holding circuit.

In this thesis, the lightning detection system was developed that is simple and cheaper than lightning detection system owned by Weather Forecasting Company or some others research company that huge in size and very costly. The method are using of one wire antenna and a pair of orthogonal loop antenna. The distance and direction was calculated using of formula deduce from previous researcher. The ratio between magnetic field and electric field is the method of determining the distance of lightning strike. The direction of lightning strike was determined by using of inverse tangent formula. The formulas showed in the next chapter.

1.2 Problem Statement

Lightning detector own by Weather Forecasting Company or some others research company usually very huge in size and costly. So, this kind of lightning detection system are seldom own by public individual. The information about lightning strike location is very important for public citizens to avoid them from danger especially the persons undergoing an outdoor activity. Therefore, to know the location of lightning strikes occurs, it is often desirable to know the distance and direction. Lightning detector which able to detect the lightning strike location occurred in a small radius with a small size and cheaper cost will be the first choice for the public citizens in protecting their life from the lightning strike.

1.3 Project Objective

There are three objectives in this project which are:

- a) To develop portable lightning detector circuit where it is able to determine the distance and direction of lightning strike.
- b) To develop GUI using Microsoft Visual Basic 6.0 to display and record the data.
- c) To simulate lightning detection system circuit using Proteus.

1.4 Project Scope

In this project, lightning detection system is designed by using PIC16F877A microcontroller. The software used to write the program to microcontroller is CCS Compiler whereas the program written for Graphic User Interface (GUI) in between microcontroller and computer is done by using Visual Basic (VB) 6.0. The circuit of the project is simulated by using Proteus software. The interfacing between PIC16F877A and GUI will done through UC00A that is USB to uart converter. Besides data will display in VB 6, data of lightning strike also are displayed in LCD. All the data storing as .txt file in the laptop.

1.5 Thesis Outline

This thesis is separated into 5 chapters. Chapter 1 focuses on outlines the main idea of this project. Chapter 2 would explained about lightning phenomenon, typical way of determining the location of lightning strike, and literature review of previous researcher. Chapter 3 would describe the methodology of the project, including the tools, equipments, procedure and processes involved for the hardware and software development of the entire project. In chapter 4, results obtained from the lightning detection system would be discussed in this chapter. Chapter 5, which is the last chapter, would make a conclusion for this thesis and recommendations that can be used in further research related to this topic in future would be included.

CHAPTER 2

FUNDAMENTAL OF LIGHTNING

2.1 Lightning Phenomenon

Lightning, an awesome and terrifying natural phenomenon, is really nothing more than an electrical discharge that happens to be at an enormous voltage. The natural hazard strikes billion of times, kills thousands of people and damages billions of assets per year. The sheer power of a lightning strike, combined with the brightness and intensity of the flash that comes with it make it one of the most gorgeous natural phenomenon in existence. The figures (2.1-2.8) are the most incredible shots of lightning in nature.



Figure 2.1: Volcano Storm



Figure 2.2: Sheet Lightning



Figure 2.3: Split Lightning



Figure 2.4: Desert Storm



Figure 2.5: Positive Lightning



Figure 2.6: Circle Strike



Figure 2.7: Ball Lightning



Figure 2.8: Multi-Strike

2.2 How Does Lightning Occur

Lightning is the result of a large charge separation within a cloud. Clouds are composed of millions of ice particles and water droplets. These particles collide with other condensing moisture as it rises, and when they do, electrons are knocked loose. These electrons build up at the bottom of a cloud and make it negatively charged. The rising moisture molecules, now missing electrons, become positively charged and gather at the top of the cloud. This creates a charge separation, which has an electric field that is negative at the bottom and positive at the top. As the collisions continue, the electric field builds so strong that it gives the planet's surface a positive charge. When these charges become powerful enough, the cloud's electricity is discharged toward the Earth's surface, which results in lightning.

2.3 Types of Lightning

There are various different types of lightning besides the standard cloud to ground strikes.

a) Cloud to Ground

This is the discharge from the negative lower part of the cloud to the positively charged earth. This is the most common form thought of when lightning is mentioned to people however it only constitutes 25% of all lightning however it is also the type that causes the most damage and so effects our lives the most.

b) Intracloud Lightning

Intra-cloud lightning is the most common form of lightning. It appears as a flash within the cloud occurring between the positive and negative charges that are within the same thunder cloud. Although this is the most common due to it causing very little danger or damage not alot of research has been carried out on it in comparison to cloud to ground.

c) Intercloud

The least common is the strike between the positive and negative charges within separate clouds where the strike travels in between them.

d) Ball Lightning

This appears in the form of a glowing sphere which drifts horizontally in the air usually only lasting a few seconds. It is still not fully understood why this occurs, one interesting theory that was recently found was by Abrahamson and Dinniss in 2000 is to do with the soil type at the place of the strike. This idea comes in three parts.

- i. A heated mixture with more carbon content than silicon can cause the silicon to separate out into a very light fluffy form which is capable of floating in air.
- ii. The temperature of approximately 3000C where the lightning strikes.
- iii. The mixture of carbon and silicon found in the soil.

So, bearing in mind the previous elements if lightning strikes in an area where the soil has the correct make up then a ball of silicon would be created and due to its light nature would hover in the air. The light emitted then is believed to be the oxidization of the silicon which would explain why the ball gives off such light and then fades away, as this would occur when the oxidization is complete.

2.4 What Happen When People and Lightning Converge

Men are struck by lightning four times more often than women. According to a study by Ronald L. Holle and Raúl E. López of the National Severe Storms Laboratory and E. Brian Curran of the National Weather Service from 1959 – 1994, males account for 84% of lightning fatalities and 82% of injuries, men can take comfort in the fact that the actual number of deaths and injuries from lightning strikes has decreased in the past 35 years.

Holle's team attributes 30 percent of the decrease in lightning deaths to improved forecasts and warnings, better lightning awareness, more substantial buildings, and socioeconomic changes. They attribute an additional 40 percent to improved medical care and communications.

The National Weather Service publication Storm Data recorded 3,239 deaths and 9,818 injuries from lightning strikes between 1959 and 1994. Still, many doctors do not fully understand how to treat the injuries of the other 80 percent of lightning victims who survive a strike. Lightning injuries are not the same as electrical shocks. For one thing, the contact voltage of a typical industrial electrical shock is 20 to 63 kilovolts, while a lightning strike delivers about 300 kilovolts.

Industrial shocks rarely last longer than half a second (500 milliseconds) because a circuit breaker opens or the person is thrown far from the live conductor. Lightning strikes have an even shorter duration, only lasting up to a few milliseconds. Most of the current from a lightning strike passes over the surface of the body in a process called "external flashover."

Both industrial shocks and lightning strikes result in deep burns at point of contact, for industry the points of contact are usually on the upper limbs, hands and wrists, while for lightning they are mostly on the head, neck and shoulders. Industrial shock victims sometimes exhibit deep tissue destruction along the entire current path, while lightning victims' burns seem to center at the entry and exit points. Both industrial shock and lightning victims may be injured from falling down or being thrown and the leading cause of immediate death for both is cardiac or cardiopulmonary arrest.

If you survive a shock, you still have to deal with the consequences of the electrical burns. Industrial shock burns can lead to kidney failure, infection, muscle and tissue damage, or amputation. Lightning burns are exceptionally life threatening. 70 percent of lightning survivors experience residual effects, most commonly affecting the brain (neuropsychiatric, vision and hearing). These effects can develop slowly, only becoming apparent much later

2.5 Lightning Strike Locating Technique

Electrostatic field is generated when lightning striking on the ground due to the existing of electric charges. Electromagnetic field will generated with the moving electron which travels from the cloud to the ground. There are a lot research had been done on determination of lightning strike location. Basically, most of the researches are started by detecting the electrostatic field and electromagnetic field generated by the lightning strike. Besides electrostatic field and electromagnetic field, thunder storm is a famous characteristic of lightning strike used by the researchers in some lightning strike

locating systems. There are two parameters need to be determined in order to locate lightning strike location which are the lightning strike distance and its direction.

2.5.1 Determination of Lightning Strike Distance

The lightning strike distance can be determined by two methods that is by using delay in time of arriving technique (TOA) and ratio between electromagnetic field and electrostatic field. The TOA method is implemented by using two kinds of antennas which are wire antenna used to sense the electrostatic wave and the acoustic antenna is used to sense the pressure wave produce by the thunder storm when lightning strike to the ground. The pressure wave produces by the thunder storm is propagating with the average speed of around 350 m/s while the electrostatic wave is propagating with the speed of light. The delay in time for the acoustic antenna to sense the pressure wave compare with the wire antenna to sense electrostatic wave can be used to calculate the distance of lightning strike by the following formula by assuming the speed of electrostatic wave is very fast compare with the speed of thunder storm:

$$D = V_T \times T_D(1)$$

where ,

- D = distance of the antenna in meter
V = average speed of thunder storm which is 350 m/s
T = time delay between acoustic antenna and wire antenna in second

The method to detect lightning strike occurred using the ratio between electromagnetic field and electrostatic field consist a pairs of loop antennas and a wire antenna. A pairs of loop antenna is used to sense the magnetic field produce by the lightning strike and a wire antenna is used to sense the electric field produce by the lightning strike. Next, these two signals are then fed into a ratio meter to get the signal which is the ratio of the two input signal. The output signal from the ratio meter is proportional to the distance of the lightning strike.

2.5.2 Determination of Lightning Strike Direction

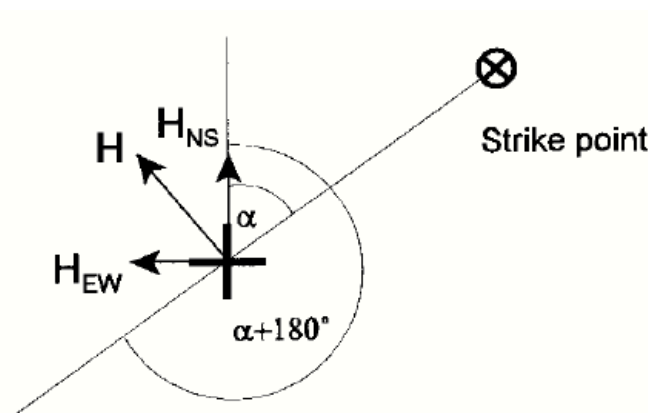


Figure 2.9: Determination of the Angle to the Lightning Strike Point

The direction of lightning strike is usually determined by using a pairs of loop antenna which is place perpendicular to each other. Each of the loop antennas is used to sense the magnetic field produce by the lightning strike. The angle to the lightning strike point is determined by the ratio from the two loop antennas with the following formula:

$$\tan \alpha = H_{NS} / H_{EW}(2)$$

2.6 Review of previous research

Previous research of lightning strike locating technique to detect the distance or direction lightning strike were discussed in this session.

2.6.1 Lightning Detection System with Sferics Observation at a Single Station

by Satoshi Yagitani, Isamu Nagano and Mitsunori Ozaki.

This paper developed a lightning detection system to determine the lightning locations by observing the sferic waveforms at a single station. This system uses a crossed loop antenna to receive two horizontal magnetic components and a dipole antenna to receive a vertical electric component of VLF signals. The observed waveform

of each sferic usually consists of a series of sequential pulses. The first pulse coming directly from a lightning return stroke is used to find the direction to the lightning. The distance to the lightning is then determined by the time-of-arrival difference between the direct pulse and each of the subsequent pulses, which are the multiple reflections of the first pulse between the ionosphere and the ground.

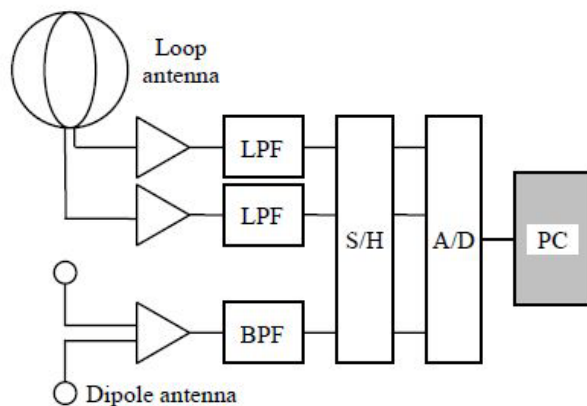


Figure 2.10: Antenna Design

They observe two orthogonal horizontal components of magnetic field and one vertical component of electric field in the VLF frequency range in order to estimate both the distance and direction of the lightning. The east-west and north-south components of the horizontal magnetic fields are measured by two orthogonal loop antennas, each of which has the diameter of 0.8 m. On the other hand the vertical electric field is picked up by a dipole antenna with a tip-to-tip length of 1 m, where at the tip of each element of the dipole is attached a sphere probe. These 3 channels of the observed signals are amplified and band-pass-filtered in the frequency range between 1 kHz and 14 kHz. The lower cut off of 1 kHz is chosen to reduce the ham noise of the commercial power lines (60 Hz and harmonics), while the upper cut off of 14 kHz is used for anti-aliasing. Then the 3 channels of wave forms are simultaneously digitized by an A/D board connected to a PC, with the sampling frequency of 66.67 kHz and a 16-bit resolution for each channel. They can accurately calibrate the digitized data to obtain the absolute wave

forms of electromagnetic fields, by taking into account the transfer functions (frequency responses) of the antennas and analogue circuits.

The digitized wave forms are continuously recorded onto a ring buffer memory, where the instantaneous levels of the wave forms are continuously monitored. When they detect an intense pulse larger than a certain threshold (called “triggering”), then the wave forms over the duration of 640 msec, which starts 64 msec before the triggering, are stored on a hard disk with a time stamp. Thus they can automatically save the complete wave forms of intense pulses, which usually correspond to the lightning-generated VLF sferics. By extracting a sequence of pulses from the recorded and calibrated electromagnetic wave forms of each of the sferics, the system calculates the distance and direction of the corresponding lightning return stroke.

2.6.2 Lightning Strike Distance Detector

by Koay Kim Leong

In this project, lightning strike distance detector (LSD detector) was designed and implemented by using PIC micro-controller. The modules involved in LSD detector include three active A/D channels that will be attached to one wire antenna and two orthogonal loop antenna. The author use three voltage divider to give the signal from lightning strike. The output voltage from each voltage divider would act as virtual input to the system that representing the electromagnetic field strength of a lightning strike. These analog voltages are then fed into corresponding analog input pin of PIC microcontroller respectively by using a push to on button. In-built analog to digital (A/D) converter module of PIC16F877A would convert the analog input to digital form.

A serial port was also introduced and configured to connect LSD detector to the personal computer for data display and data storage by using GUI. The distance was calculated by using formula deduced from previous researcher who arrived at a conclusion that the ratio of magnetic field to the electric field is proportional to the distance of lightning strike. On the other hand, the direction of the lightning strike was determined by using inverse tangent formula. All the formulas were programmed in PIC16F877A. Last but not least, the output of this project would be displaying the distance and direction on computer whenever there is a signal detected from the A/D channel of PIC microcontroller.

2.6.3 Time-to-Thunder Method of Lightning Distance Determination

by Wan Ismail Ibrahim and Zulkurnain Abdul Malik

In this paper, the authors develop a system to determine the lightning strike distance from the measuring point. They use the time-to-thunder method to determine the strike distance. The technique was implemented using two kinds of sensors, namely, a broadband antenna to detect the electric field, and a microphone to detect the acoustic signal produced when lightning strikes the ground. A broadband parallel plate antenna was used to detect the electric field signal. The acoustic signal was detected by a microphone. Both of these sensors were combined to form a single-station lightning observation system. The arrival time-delay between both signals was used to calculate the strike distance. In the software development, a graphical user interface (GUI) program was developed using LabVIEW 8.5 software that used as a data logger to calculate the distance and to save the data. Both developed hardware and software were integrated by using a NI-GPIB Visa and a Picoscope 5000 Series. The lightning distance data were recorded for duration from January 2010 until March 2010 using the developed system. The range of the lightning detection is up to 10 km in radius.

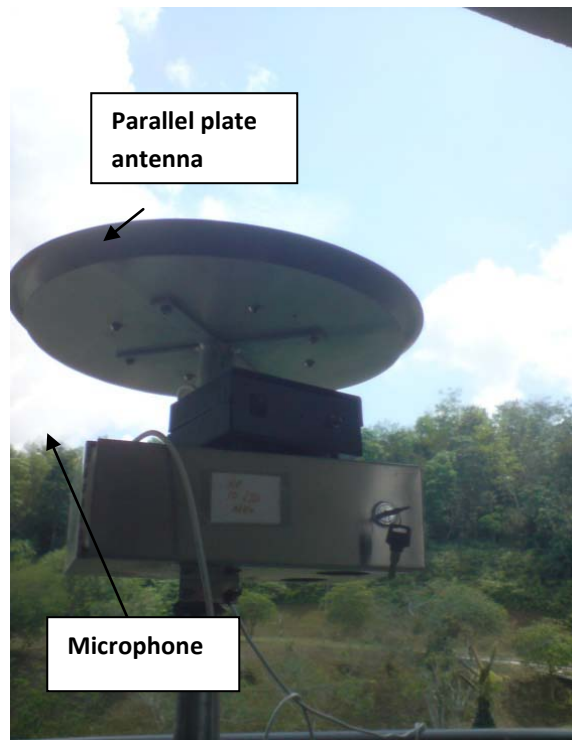


Figure 2.11: Antenna to Detect Lightning

2.6.4 World Coverage for Single Station Lightning Detection

by C. Mackay and A.C Fraser Smith

The authors were analyze the global coverage and effectiveness of a single station lightning location method. For this method, magnetic fields are recorded on the Earth's surface at frequencies in the extremely low frequencies (ELF; 30–3000 Hz) and very low frequencies (VLF; 3–30 kHz). The measurements of magnetic field in the north-south and east-west directions were employed by two crossed loop antenna.. Lightning can be modeled as a vertical dipole with the current passing through it resembling an impulse waveform. A broad range of frequencies of electromagnetic

waves are excited by this impulse. The higher frequencies dissipate into the ionosphere, while the lower frequencies, such as the VLF and ELF waves, are trapped between the Earth's surface and the lower ionosphere and propagate along through this waveguide. Remote stations record the electromagnetic waves emitted by the lightning which forms a signal known as a sferic.

2.6.5 Implementation and Use of Lightning Detection Network in Malaysia

by Noradlina Abdullah, Mohd Pauzi Yahaya, and Dr Nadiyah Salwi Hudi

Lightning has been a major cause of power interruptions in Tenaga Nasional Berhad (TNB), one of power utility in Malaysia as this country is among the countries with the highest lightning activities in the world. In an effort to reduce the impact of lightning in TNB, TNB Research Sdn. Bhd. (TNBR), a research arm of TNB, has installed a Lightning Detection Network (LDN) in Peninsular Malaysia in 1994. After ten years of operations, the network was upgraded to include sensors with better location accuracy and sensitivity. In December 2003, the network consists of five IMPACT ESP sensors and two LPATS IV sensors were successfully commissioned. Continuous monitoring of sensors performance for upgraded network is being carried out by Lightning Detection System Laboratory operated by TNBR. This paper presents TNBR experience in the development and use of the network in TNB. Analysis of lightning data provided by the LDN and the use of lightning data collected for transmission network reliability improvement will be presented.

2.6.6 Lightning Sensors for Observing, Tracking, and Nowcasting Severe Weather

by Colin Price

This paper presents a range of ground-based lightning sensors that can be used for tracking, monitoring and even nowcasting of thunderstorms that produce hazardous weather conditions around the globe. The author use these sensors detect the electromagnetic radiation emitted by lightning discharges in different frequency bands, from very high frequencies (VHF) in the megahertz range, to very low frequencies (VLF) in the kilohertz range, and even extremely low frequencies (ELF) in the 3-300 Hz range. The different sensors can detect different aspects of the lightning flash, and at different ranges. Sensors using lower detection frequencies manage to detect lightning to greater distances. However, as the frequency decreases so does the spatial accuracy and the detection efficiency.

Depending on the hazard imposed by severe weather, the author chose the different detection systems. The protection of a small area such as an airport, nuclear power plant, sports event, etc., would benefit greatly from a VHF system that can detect all lightning types, both within and below clouds, while mapping the 3-D structure of each lightning discharge within a storm. For hazards in remote regions, such as civil aviation over the Mediterranean Sea, VLF systems are preferable, giving regional real time coverage of the location, development and motion of thunderstorms. For global studies of lightning climatology for risk assessment, the author use ELF systems, supplying an integration of the lightning activity on a regional or global scale continuously, while also being able to detect individual intense lightning discharges anywhere on the globe.

CHAPTER 3

METHODOLOGY

3.1 Overview

Through this chapter, all process involved in project construction will be discussed. Planning of time is the first step has been done upon the development of single-station lightning detection system. This is important as to make sure the development process will be finished before the deadline.

The theoretical and techniques was used in this project development. The electronic component implementations, programming tools and also the hardware procedures development would be contributing to the project succeed. Block diagram of the development of single station lightning detection system shown in Figure 3.1.

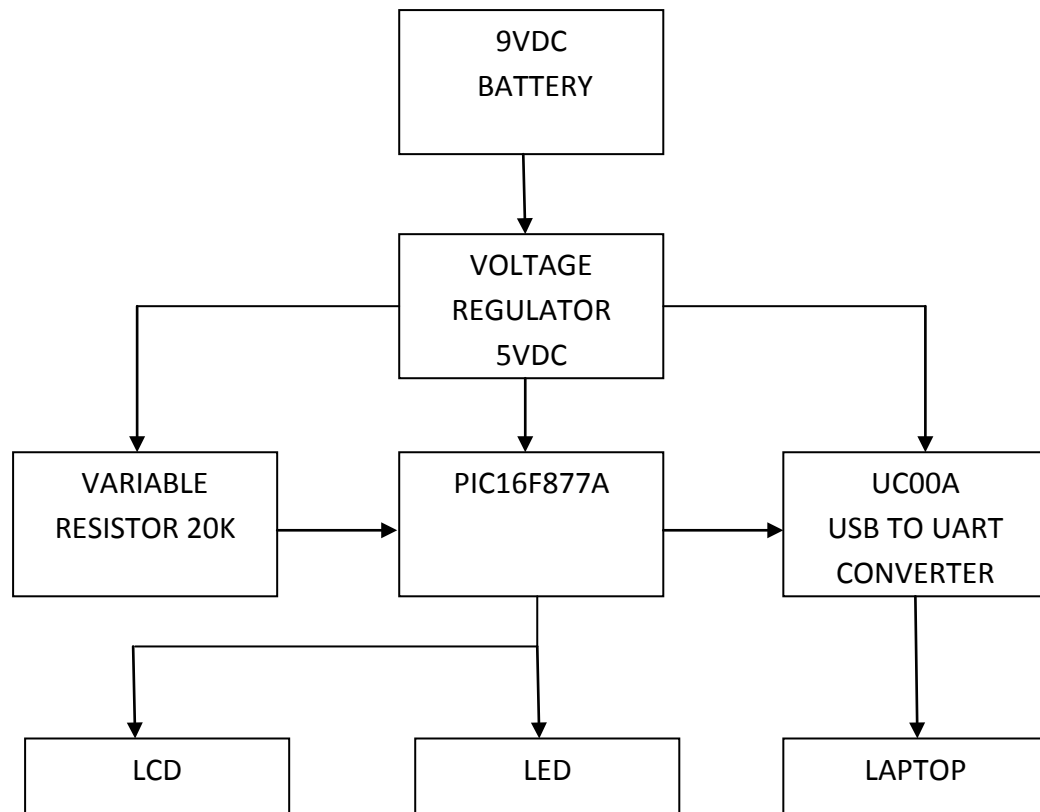


Figure 3.1: Block diagram of the project

Figure 3.1 above shows the overview of the whole project ‘Development of Single Station Lightning Detection System’. The unregulated 9VDC battery would pass through LM7805 integrated circuit (IC) which acts as a regulator to produce a regulated 5VDC voltage supply. The regulated 5VDC is used to provide a constant voltage supply to electronic circuits especially the microcontroller and usb to uart converter. Meanwhile, three variable resistors used in this project.

The variable resistors produce the output voltages which act as virtual input to the system that representing the electromagnetic field strength of a lightning strike. The output voltages can be varies according to the resistance of variable resistor. The higher the resistance of variable resistor, the higher the output voltages goes. These analog voltages are then fed into corresponding analog input pin of PIC16F877A respectively by using a push button. In-built analog to digital (A/D) converter module of PIC16F877A would convert the analog input to digital form. Distance and

the direction of a lightning strike are calculated after the conversion done by using the formula that programmed into the PIC microcontroller.

The code programmed at CCS compiler will save as *hex* file. PIC Kit 2 is a software to burn the program created to PIC16F877A. Meanwhile, USB PIC Programmer V2009 is a hardware to burn the program in PIC microcontroller. This is important to know is it PIC microcontroller is working or not. To make this project success, the circuit of the project weredesigned and simulated in Proteus.

Data of electric field, magnetic field 1, magnetic field 2, distance and direction of a lightning strike is then transferred to graphic user interface (GUI) at the laptop by using UC00A. Once the GUI detects the data transferred from PIC microcontroller, it would display and save the data, date and time into the laptop. The software required to perform this action is Microsoft Visual Basic 6 (VB 6). All code to ensure PIC16F877A will interface with VB 6 was written. Data of distance and direction of lightning strike also displayed in LCD 16x2 and LED will blink when lightning strike occurred.



Figure 3.2: Hardware of the project

3.2 Equation Involved

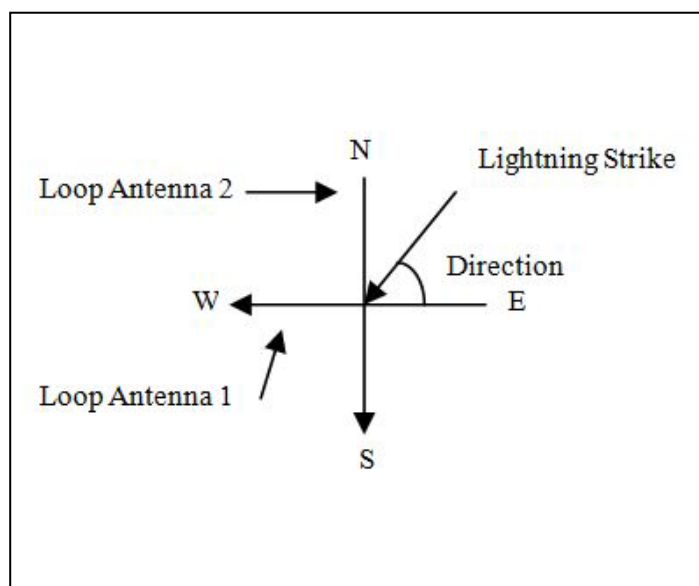
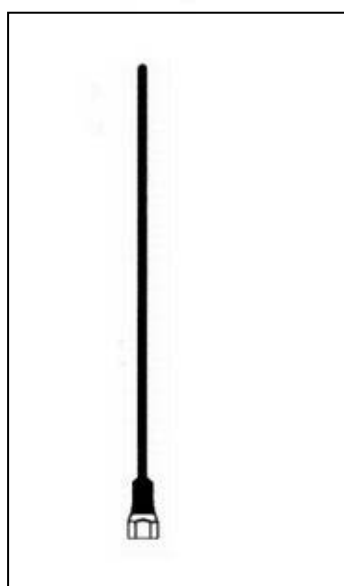


Figure 3.3 a. Wire Antenna **Figure 3.3 b.** A pair of loop antenna

A. Estimation of distance

The method in determine the distance of lightning strike is using the ratio between magnetic field and electric field. The formula as below:

$$\text{Distance} = \frac{K\sqrt{\text{MF1}^2 + \text{MF2}^2}}{\text{EF}} \quad (3)$$

Some modification formula above required cause of the calculation performed by PIC microcontroller always a positive value. So, this in not practical in developing this project. The new formula as below:

$$\text{Distance} = \frac{K\sqrt{(\text{MF1} - 128)^2 + (\text{MF2} - 128)^2}}{\text{EF}} \quad (4)$$

From modified formula, the signal that higher than level 128 will treat as positive value and vice versa.

B. Estimation of direction

From a pair of loop antenna that place perpendicular to each other, we can estimate the direction of lightning strike. The angle is determined by using this formula:

$$\text{Direction} = \tan^{-1} \frac{\text{MF1}}{\text{MF2}} \quad (5)$$

Some modification is required to this formula same case as to find the distance. The new formula as below:

$$\text{Direction} = \tan^{-1} \frac{(\text{MF1} - 128)}{(\text{MF2} - 128)} \quad (6)$$

Note that, the negative angle means the direction anti-clockwise from east direction.

3.3 Hardware Requirements

There are many components used in developing the project. These components will explained detail after this.

3.3.1 Microcontroller

PIC16F877A is type of microcontroller used upon the construction of the project. Several considerations have been made in choosing the most suitable microcontroller to be used through this project. The important specification in choosing microcontroller is the A/D converter module as the microcontroller had to convert the input analog signal to digital form before it proceed for calculation of distance and direction. The PIC16F877A pin diagram is given in Figure 3.4 below.

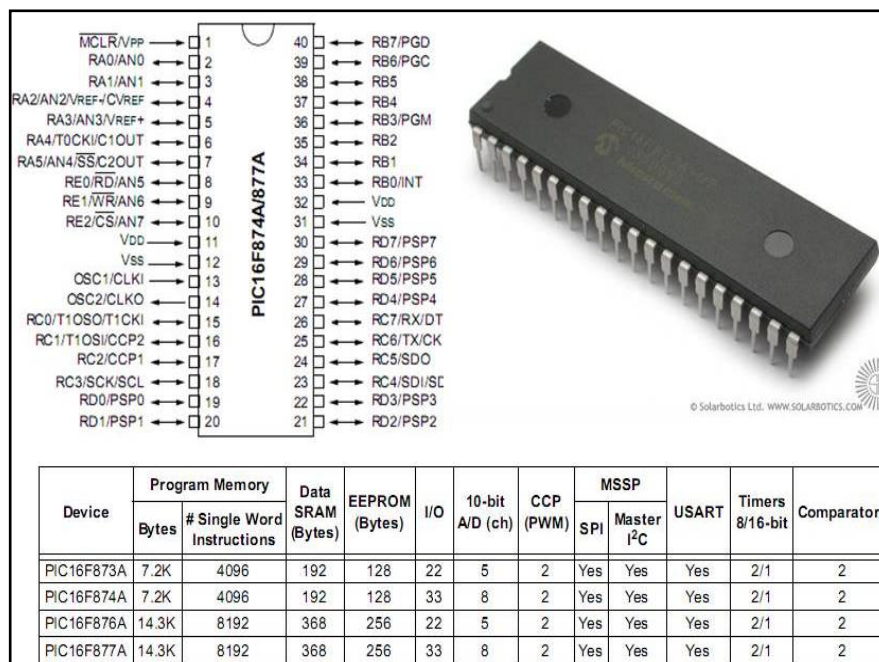


Figure 3.4: PIC16F877A pin diagram

The PIC16F877A has 33 digital I/O pins. It has a wide range of operating voltage which varies from 2.0V to 5.5V and support high frequency up to a maximum of 20 MHz. PIC16F877A uses flash memory as its program memory and it can be reprogrammed repeatedly without using ultra-violet to erase its program memory. It is also fully static or non-volatile whereby program memory in PIC16F877A would not be lost when the supply is taken off the microcontroller.

The function of this microcontroller is to detect the analog input from the generated virtual by using variable resistor. After that, the analog signal will be converted to digital signal by using the in-built A/D converter module. Next, calculation of distance and direction are also done in microcontroller. Lastly, the microcontroller is used to send data of electric field, magnetic field 1, magnetic field 2, distance and direction to laptop through the UC00A. Data of distance and direction also displayed in LCD and LED will turn ON to give the signal of lightning strike happened. The full program source code for PIC16F877A is shown in an Appendix B. Figure 3.5 shows the flow chat of microcontroller.

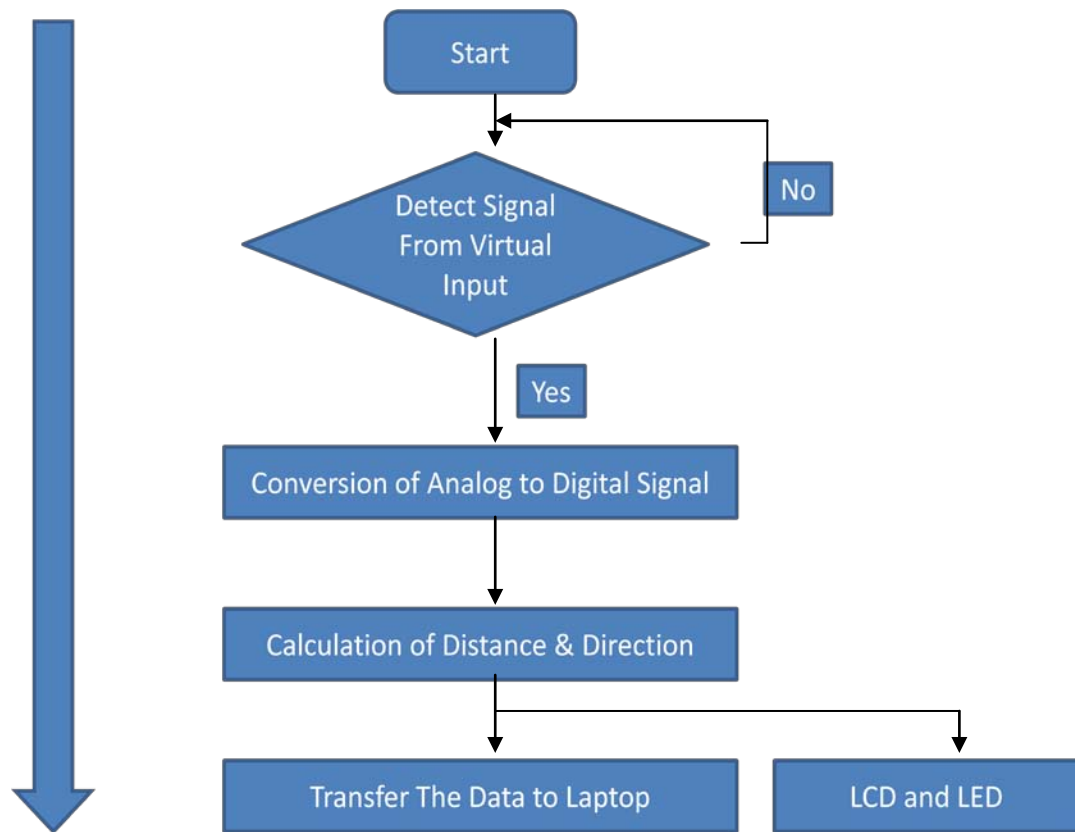


Figure 3.5: Program flow for microcontroller

3.3.2 UC00A

Serial communication is most popular interface between device and this applies to microcontroller and computer. UART is one of those serial interfaces. Classically, most serial interface from microcontroller to computer is done through serial port (DB9). However, since computer serial port used RS232 protocol and microcontroller used TTL UART, a level shifter is needed between these interfaces. Recently, serial port of computer have been phase out, it have been replaced with USB. Of course most developer chooses USB to serial converter to obtain virtual serial port. The level shifter is still necessary for UART interface. UC00A was

developed by Cytron. UC00A is a USB to UART converter which offers USB plug and play, direct interface with microcontroller and it provide low current 5V supply from USB port.

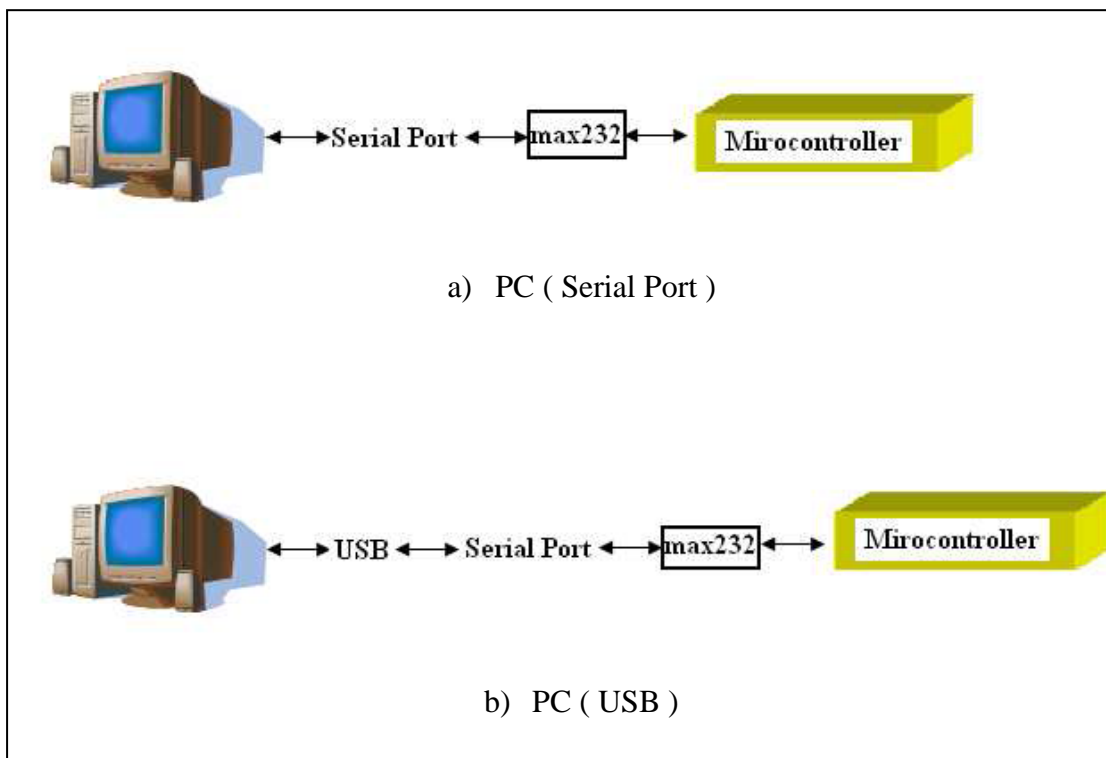


Figure 3.6: Traditional method

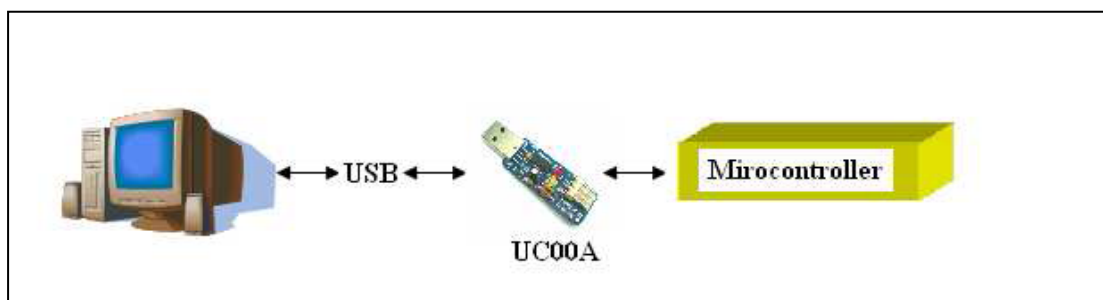


Figure 3.7: Using UC00A method

It has been designed with capabilities and features of:

- Develop low cost USB to UART converter
- Easy to use USB to UART converter, aiming development between computer and microcontroller, 5V logic.
- USB powered, no external source is required to use this converter
- 5V from USB port is available for user.
- Configurable for 5V UART interface.
- Easy to use 4 pin interface: Tx, Rx, Gnd and 5V.
- CTS, RTS, DTR and DSR is pull out to standard 2x5 header pin solder able PCB pad.
- Plug and Play
- Dimension: 4.6cm x 1.8cm

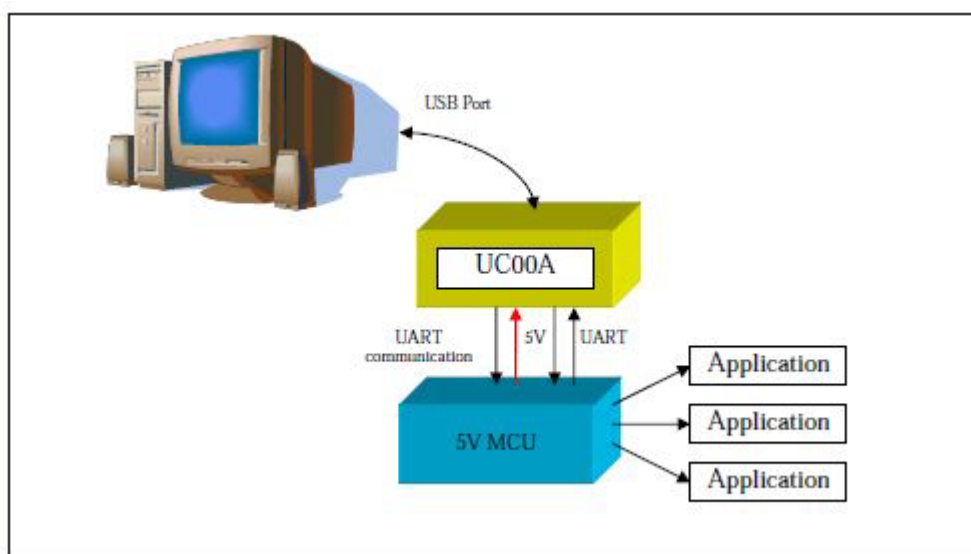


Figure 3.8: System overview of UC00A

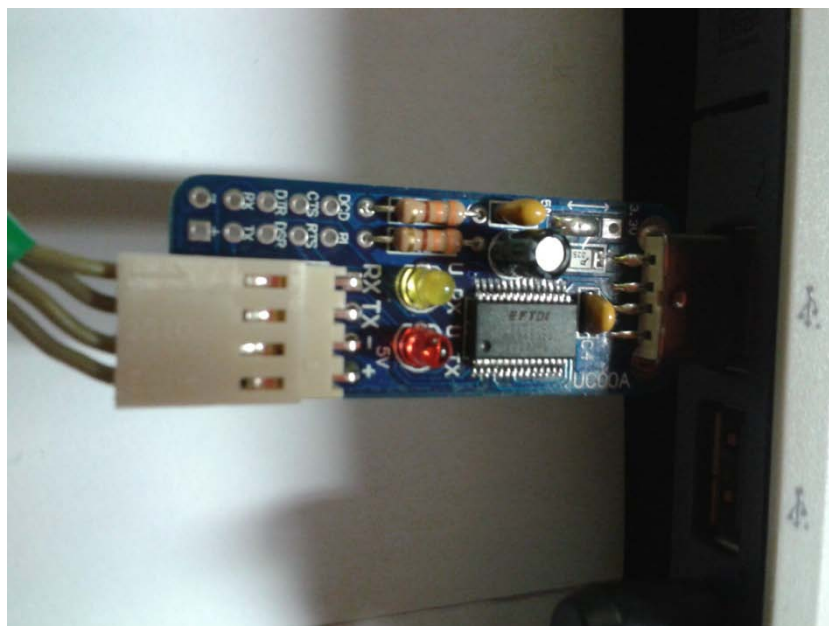


Figure 3.9: Connection of UC00A with Laptop

3.3.2.1 Board Layout of UC00A



Figure 3.10: Board layout

Table 3.1: Function of Component in UC00A

Label	Function
A	USB A type (male). This is for USB connection
B	USB to UART converter chip.
C	Two LED indicators for USB's transmitter and receiver status. These are a pair of small LED, red and yellow in color. These LEDs are connected to on board USB to UART converter. It indicates the receiver and transmitter activity. It will only work if UC00A is connected to PC or laptop through USB cable and microcontroller. Red LED indicates USB's transmitter send data, while yellow LED indicate USB's receiver receive data.
D	4 ways header pin for interface to microcontroller.
E	2 x5 extension pad for extra COM Port Feature.

3.3.2.2 Specification of UC00A

Table 3.2: 4 Ways 2510 Header Pin

Pin	Label	Definition	Function
1	+	5V Power output from UC00A	5V supply from USB, optional for user to power external device, maximum current 200mA.
2	-	Ground or negative	Ground of power and signal. This pin should be connected to device's GND pin.
3	TX	UC00A UART Transmit pin	This is UC00A's transmitter pin (5V TTL). It should be connected to device's receiver pin.
4	RX	UC00A UART Receive pin	This is UC00A's receiver pin (5V TTL). It should be connected to device's transmitter pin.

Table 3.2.1: Absolute Maximum Rating

Symbol	Parameter	Min	Max	Unit
+	Power output pin	5.0	5.0	V
-	Operating voltage	0	0	V
TX	Transmitter pin of UC00A	0	5.5	V
RX	Receiver pin of UC00A	0	5.5	V

Table 3.3: 2x5 Extension Pad

Label	Definition	Function
+	5V Power output from UC00A	5V supply from USB, optional for user to power external device, maximum current 200mA.
-	Ground or negative	Ground of power and signal. This pin should be connected to device's GND pin.
TX	UC00A UART Transmit pin	This is UC00A's transmitter pin (5V TTL). It should be connected to device's receiver pin.
RX	UC00A UART Receive pin	This is UC00A's receiver pin (5V TTL). It should be connected to device's transmitter pin.
DSR	UC00A Data Set Ready pin	This pin is unused under normal UART operation.
DTR	UC00A Data Terminal Ready pin	This pin is unused under normal UART operation.
RTS	UC00A Request To Send pin	This pin is unused under normal UART operation.
CTS	UC00A Clear To Send pin	This pin is unused under normal UART operation.
RI	UC00A Ring Indicator pin	This pin is unused under normal UART operation. (This pin is available only for Rev 1.1 UC00A)
DCD	UC00A Data Carrier Detect pin	This pin is unused under normal UART operation. (This pin is available only for Rev 1.1 UC00A)

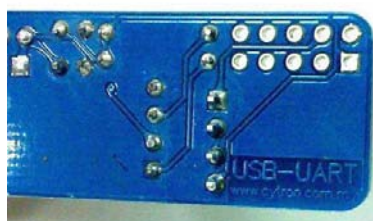


Figure 3.11: Rev 1.0

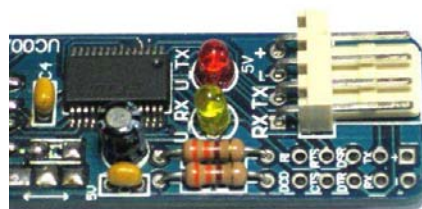
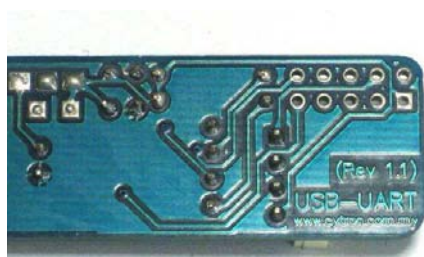


Figure 3.12: Rev 1.1

Table 3.3.1: Absolute Maximum Rating

Symbol	Parameter	Min	Max	Unit
+	Power output pin	5.0	5.0	V
-	Operating voltage	0	0	V
RS232 Signals	Signal Pins	0	5.5	V

3.3.3 Others Hardware



Figure 3.13: Lcd 16x2

Table 3.4: Pinout Functions for the LCD

Pin No.	Name	Function
1	Vss	Ground
2	Vdd	+ve supply
3	Vee	Contrast
4	RS	Register Select
5	R/W	Read/Write
6	E	Enable
7	D0	Data bit 0
8	D1	Data bit 1
9	D2	Data bit 2
10	D3	Data bit 3
11	D4	Data bit 4
12	D5	Data bit 5
13	D6	Data bit 6
14	D7	Data bit 7

The function of each of the connections is shown in Table 3.4. Pins 1 and 2 are the power supply lines, Vss and Vdd. The Vdd pin should be connected to the positive supply, and Vss to the 0V supply or ground. Although the l.c.d. module data sheets specify a 5V d.c. supply (at only a few milliamps), supplies of 6V and

4.5V both work well, and even 3V is sufficient for some modules. Consequently, these modules can be effectively, and economically, powered by batteries.

Pin 3 is a control pin, Vee, which is used to alter the contrast of the display. Ideally, this pin should be connected to a variable voltage supply. A preset potentiometer connected between the power supply lines, with its wiper connected to the contrast pin is suitable in many cases, but be aware that some modules may require a negative potential; as low as -7V in some cases. For absolute simplicity, connecting this pin to 0V will often suffice.

Pin 4 is the Register Select (RS) line, the first of the three command control inputs. When this line is low, data bytes transferred to the display are treated as commands, and data bytes read from the display indicate its status. By setting the RS line high, character data can be transferred to and from the module. Pin 5 is the Read/Write (R/W) line. This line is pulled low in order to write commands or character data to the module, or pulled high to read character data or status information from its registers.

Pin 6 is the Enable (E) line. This input is used to initiate the actual transfer of commands or character data between the module and the data lines. When writing to the display, data is transferred only on the high to low transition of this signal. However, when reading from the display, data will become available shortly after the low to high transition and remain available until the signal falls low again.

Pins 7 to 14 are the eight data bus lines (D0 to D7). Data can be transferred to and from the display, either as a single 8-bit byte or as two 4-bit “nibbles.” In the latter case, only the upper four data lines (D4 to D7) are used. This 4-bit mode is beneficial when using a microcontroller, as fewer input/output lines are required.

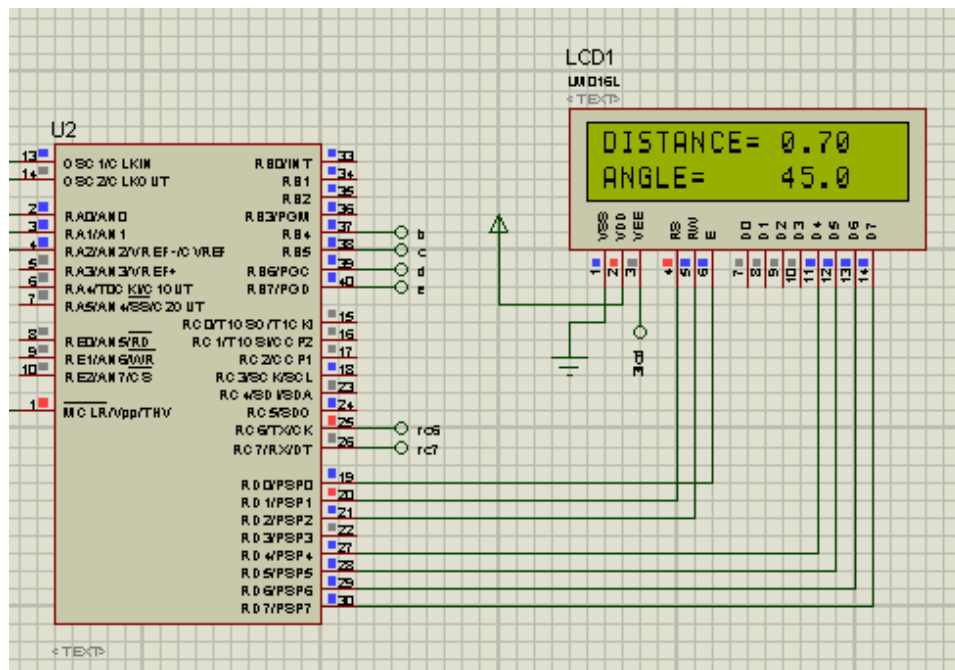
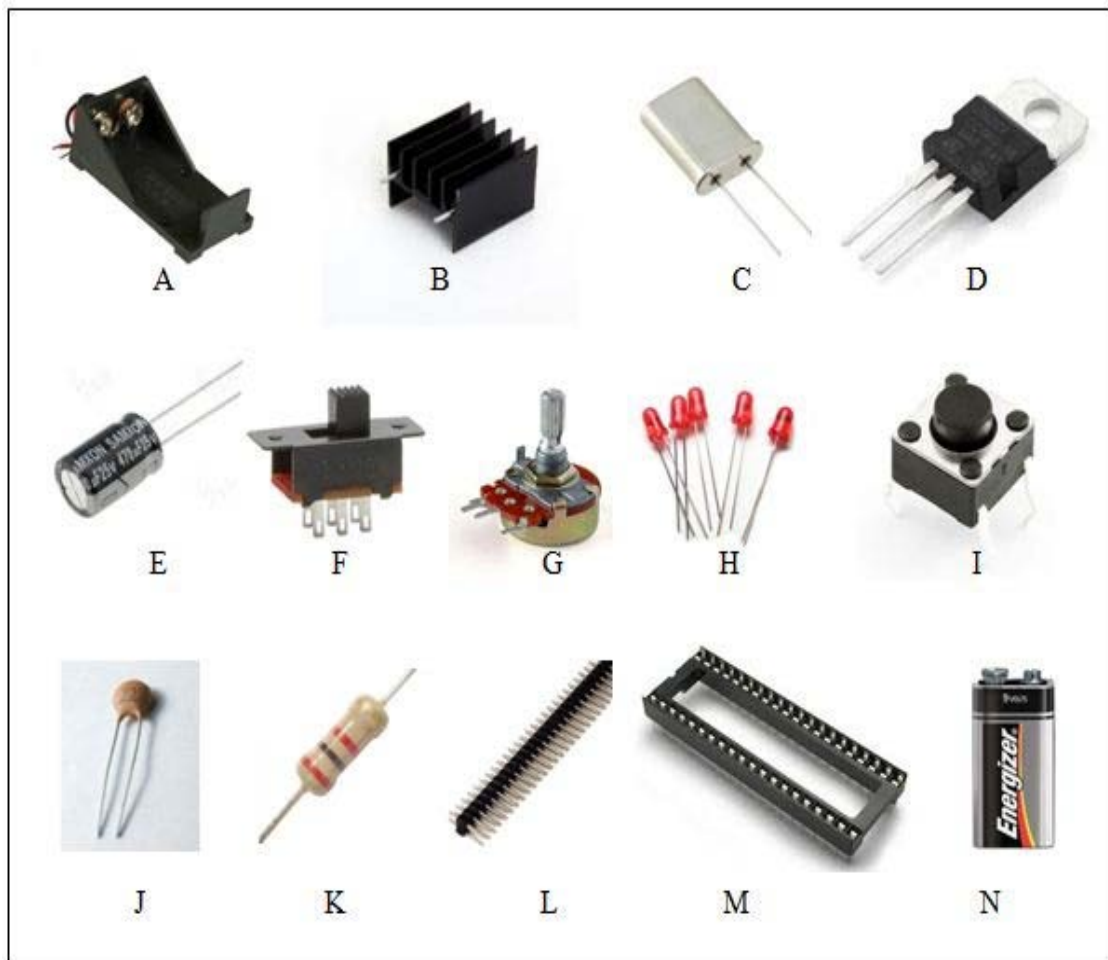


Figure 3.14: LCD Connections with PIC16F877A



Figure 3.15: USB PIC Programmer V2009



A: Battery Holder

B: Heat Sink

C: Crystal 20Mhz

D: LM7805 Voltage Regulator

E: Capacitor

F: Slide Switch

G: Variable Resistor

H: LED

I: Push Button

J: Capacitor 30pF

K: Resistor

L: Header Pins

M: IC Base

N: Battery 9VDC

3.3.4 Oscillator

PIC16F877A have the pin number 13 and 14. Those pin was named as OSC1 and OSC2. Crystal osillator from various frequency was connected to both of pin. Pulse generated from the oscillator will some time have the noise. To reduce the noise, two capacitors in piko farad value is needed. The value of capacitor is depend on the speed of oscillator that you use. Figure 3.17 below shows the way how to connect the the crystal oscillator and Table 3.5 for capacitor value needed.

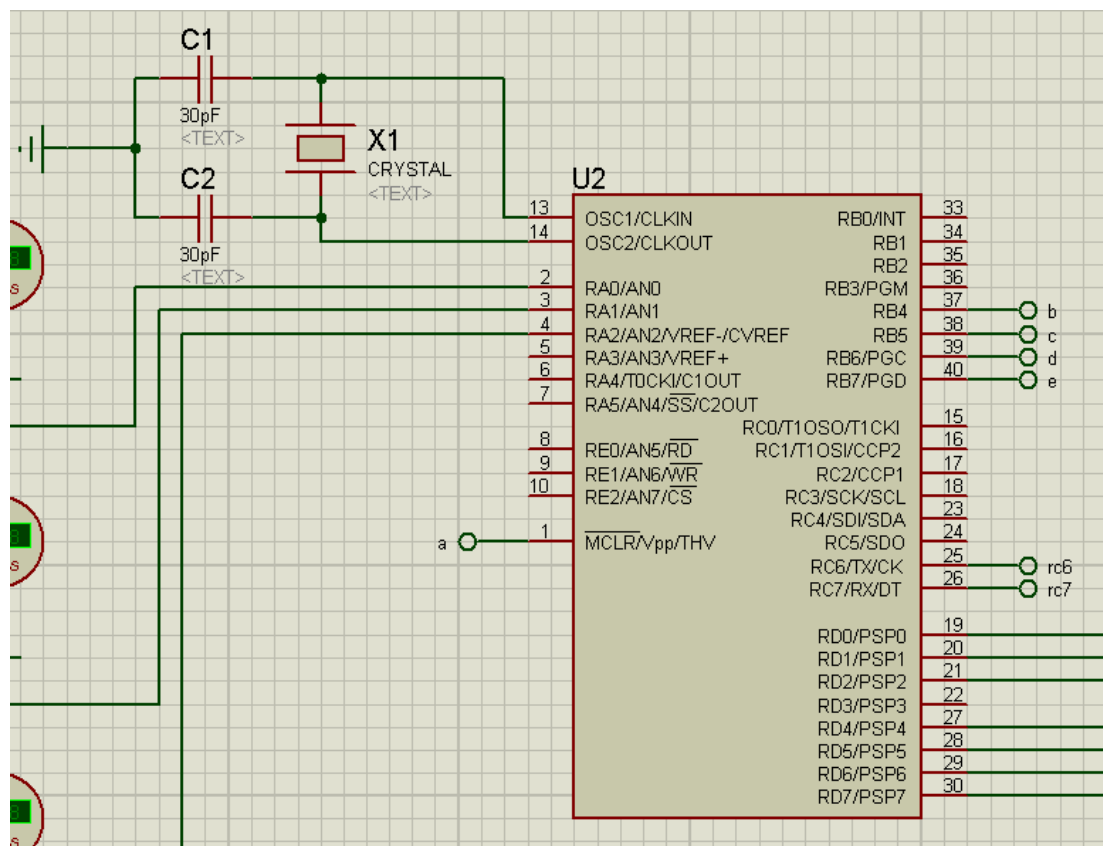


Figure 3.17: Connection crystal oscillator

Table 3.5: Capacitor value depend on crystal frequency

Oscillator Type	Crystal Frequency	Capacitor Range (C1)	Capacitor Range (C2)
LP	32 kHz	33 pF	33 pF
	200 kHz	15 pF	15 pF
XT	200 kHz	47-68 pF	47-68 pF
	1 MHz	15 pF	15 pF
	4 MHz	15 pF	15 pF
HS	4 MHz	15 pF	15 pF
	8 MHz	15-33pF	15-33pF
	20 MHz	15-33pF	15-33pF

3.3.5 Reset Pin

There are 7 pins should be connect in order PIC operate. 4 pins is already connected which is 2 pins for 5V and 2 pin for ground (negative). It 3 more pins left. The other important pin is Reset pin (MCLR - Master Clear Reset at Pin number 1). If PIC read 0V at MCLR pin, it will reset the program, so if MCLR pin not connected with 5V, PIC will remain reset and the program will not execute. You can directly connect the MCLR with 5V but it will unable to reset if the system goes wrong.

Logic condition must be created which is 1 and 0 to the reset pin to ensure the reset button can use. 1 is mean the reset pin get 5V. If the reset pin logic is 1, then the program in PIC will execute, but if the reset pin logic condition is 0 (which is 0V) then PIC will not execute the program.

Table 3.6: Program status for reset function of PIC16F877A

Logic Condition	Voltage	Program Status
0	0V	Not Execute
1	5V	Execute

Pull up resistor must be installed to get that condition. When the switch is not pushed, current will flow through 47K resistor and MCLR Pin. As a result, MCLR Pin receive 5V and PIC read it as logic 1. But when switch is push, current will flow through 47K resistor, switch and directly to ground. There is no voltage will receive at MCLR Pin. This give 0 logic at MCLR Pin.

3.3.6 PIC16F877A ADC Configuration

There are only FOUR registers need to understand to configure the ADC. They are ADCON0, ADCON1, ADRESH and ADRESL. The two most important ones are ADCON0 and ADCON1. ADRESH and ADRESL are just the registers where the ADC stores the result of the conversion. The ADC flow as Figure 3.18 below.

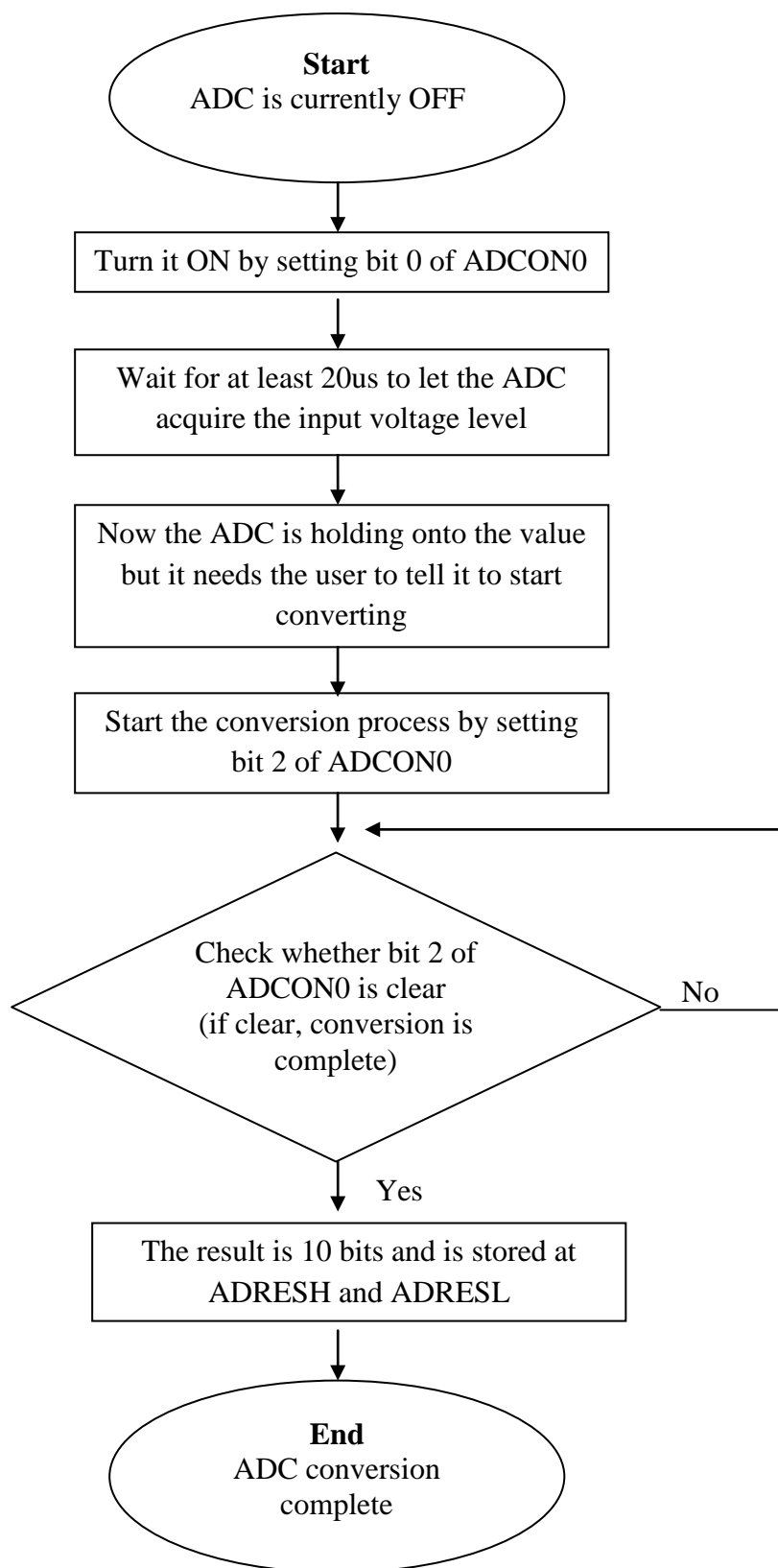


Figure 3.18:ADC flow

ADCON0 is split into four separate parts, the first part consists of the highest two bits ADCS1 and ADCS0, and sets the clock frequency used for the analogue to digital conversion, this is divided down from the system clock (or can use an internal RC oscillator), if 20MHz clock used, so $F_{osc}/32$ choosed (as given in the table below).

Table 3.7: ADC clock select bits

ADCS1	ADCS0	A/D Conversion Clock Select bits.	Max. Clock Freq.
0	0	$F_{osc}/2$	1.25MHz
0	1	$F_{osc}/8$	5MHz
1	0	$F_{osc}/32$	20MHz
1	1	Frc (Internal A2D RC Osc.)	Typ. 4 μ S

The second part of ADCON0 consists of the next three bits, CHS2, CHS1 and CHS0, these are the channel select bits, and set which input pin is routed to the analogue to digital converter.

Table 3.8: Channel select bits

CHS2	CHS1	CHS0	Channel	Pin
0	0	0	Channel0	RA0/AN0
0	0	1	Channel1	RA1/AN1
0	1	0	Channel2	RA2/AN2
0	1	1	Channel3	RA3/AN3
1	0	0	Channel4	RA5/AN4
1	0	1	Channel5	RE0/AN5
1	1	0	Channel6	RE1/AN6
1	1	1	Channel7	RE2/AN7

The third part is a single bit (bit 2), GO/DONE, this bit has two functions, firstly by setting the bit it initiates the start of analogue to digital conversion, secondly the bit

is cleared when the conversion is complete .The fourth part is another single bit (bit 0), ADON, this simply turns the A2D On or Off, with the bit set it's On, with the bit cleared it's Off , thus saving the power it consumes.

Table 3.9: Bits required in ADCON0

Input	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
AN0	1	0	0	0	0	0	-	1
AN1	1	0	0	0	1	0	-	1

ADCON1 is really a little more complicated, although it's only split into two sections. The first section is a single bit, ADFM, this is the Result Format Selection Bit, and selects if the output is Right Justified (bit set) or Left Justified (bit cleared). The advantage of this is that it makes it very easy to use as an 8 bit converter (instead of ten bit).By clearing this bit, and reading just ADRESH, 8 bit result get, ignoring the two least significant bits in ADRESL.PCFG3-0 are probably the most complicated part of setting the A2D section, they set a lot of different options, and also limit which pins can be analogue, and which can be digital:

Table 3.10: PCFG3-0

PCFG3: PCFG0	AN7 RE2	AN6 RE1	AN5 RE0	AN4 RA5	AN3 RA3	AN2 RA2	AN1 RA1	AN0 RA0	Vref+	Vref-
0000	A	A	A	A	A	A	A	A	Vdd	Vss
0001	A	A	A	A	Vref+	A	A	A	RA3	Vss
0010	D	D	D	A	A	A	A	A	Vdd	Vss
0011	D	D	D	A	Vref+	A	A	A	RA3	Vss
0100	D	D	D	D	A	D	A	A	Vdd	Vss
0101	D	D	D	D	Vref+	D	A	A	RA3	Vss
0110	D	D	D	D	D	D	D	D	Vdd	Vss
0111	D	D	D	D	D	D	D	D	Vdd	Vss
1000	A	A	A	A	Vref+	Vref-	A	A	RA3	RA2
1001	D	D	A	A	A	A	A	A	Vdd	Vss
1010	D	D	A	A	Vref+	A	A	A	RA3	Vss
1011	D	D	A	A	Vref+	Vref-	A	A	RA3	RA2
1100	D	D	D	A	Vref+	Vref-	A	A	RA3	RA2
1101	D	D	D	D	Vref+	Vref-	A	A	RA3	RA2
1110	D	D	D	D	D	D	D	A	Vdd	Vss
1111	D	D	D	D	Vref+	Vref-	D	A	RA3	RA2

There are actually four different options being set here:

- Setting a pin to be an analogue input.
- Setting a pin to be a digital input.
- Setting the positive reference for the converter (Vref+).
- Setting the negative reference for the converter (Vref-).

As example to decide what settings that are actually require is only using analogue inputs AN0 and AN1, which if look down the columns eliminates four of the possibilities (0110, 0111, 1110 and 1111, shaded in blue). Secondly using a VRef- of Vss (Ground), so that eliminates another four (1000, 1011, 1100 and 1101, shaded in yellow) - so eight possibly choices left (down to 50% already). Thirdly an external VRef+ reference used, need RA3 allocating to Vref+, this eliminates a further four (0000, 0010, 0100 and 1001, shaded in green). This make four possible choices and, to be honest, any of the four would work quite happily. However, one of our requirements was 'two analogue inputs', this eliminates a further three possibilities (0001, 0011 and 1010, shaded in red) - which leaves the only option which fits all our requirements '0101', so this is the value that need to write to PCFG3:PCFG0. So it need to set ADCON1 to, binary '10000101', with 0's in the places of the unused bits, this gives us two analogue inputs, Vref+ set to RA3, and Vref- set to Vss.

Table 3.11: Bits required in ADCON1

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADCON1	1	-	-	-	0	1	0	1

3.4 Software Requirement

In this section, code for PIC microcontroller was developed. A graphical user interface (GUI) also needed for the data transfer from PIC microcontroller to the laptop

3.4.1 CCS C Compiler

CCS provides a complete, integrated tool suite for developing and debugging embedded applications running on Microchip PIC® MCUs and dsPIC® DSCs. Development tools offered by CCS include an optimized C compiler, in-circuit programmers/debuggers, production programmers and complete development kits that contain all hardware, software and accessories needed to start the product development.

The compiler includes built-in functions to access the PIC microcontroller hardware such as `READ_ADC` to read a value from the A/D converter. Discrete I/O is handled by describing the port characteristics in a `PRAGMA`. Functions such as `INPUT` and `OUTPUT_HIGH` will properly maintain the tri-state registers. Variables including structures may be directly mapped to memory such as I/O ports to best represent the hardware structure in C.

The microcontroller clock speed may be specified in a `PRAGMA` to permit built in functions to delay for a given number of microseconds or milliseconds. Serial I/O functions allow standard functions such as `GETC` and `PRINTF` to be used for RS-232 like I/O. The hardware serial transceiver is used for applicable parts when possible. For all other cases a software serial transceiver is generated by the

compiler. The standard C operators and the special built in functions are optimized to produce very efficient code for the bit and I/O functions. The output hex and debug files are select-able and compatible with popular emulators and programmers including MPLAB IDE for source level debugging. PCW includes a powerful Windows IDE.

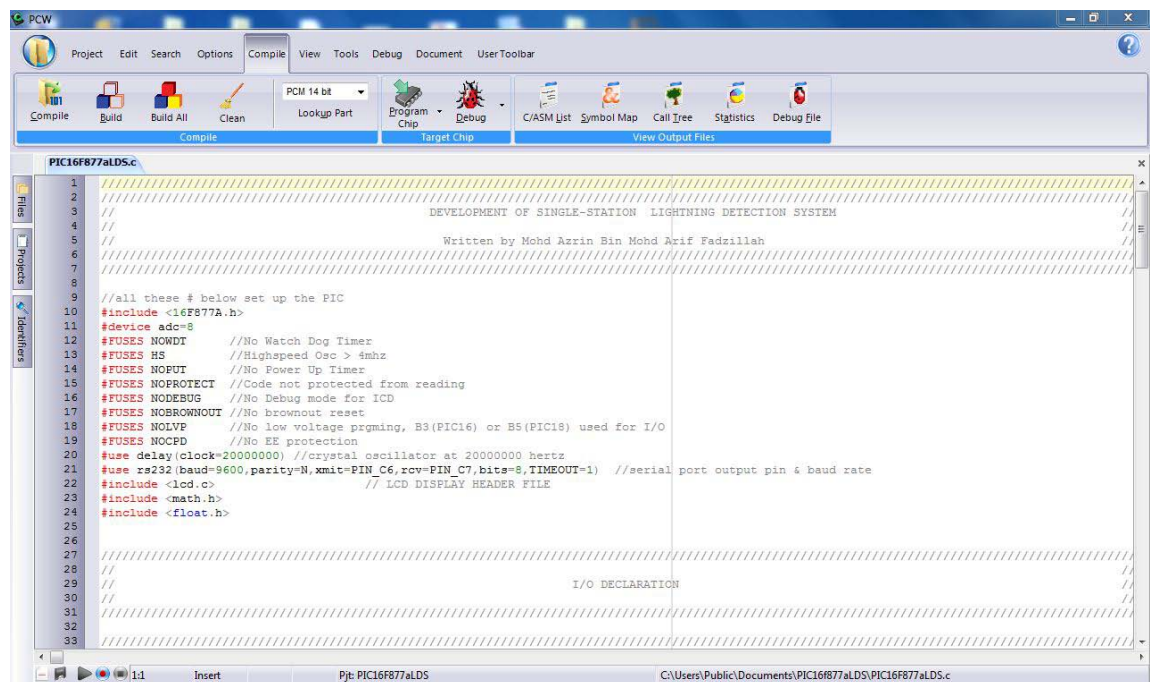


Figure 3.19 Example of Programming in CCS Compiler

3.4.2 Microsoft Visual Basic 6

Visual Basic 6 is much easier to learn than other language (Visual C++, delphi), and powerful programming language. We are easy to learn programming language with Visual Basic 6. Visual Basic 6 is a program that very popular, so many good resources that help in learning the language. We can find many tools on the internet that will spare us some programming time. Compare to other languages,

Visual Basic have the widest variety of tools that we can download on the internet and use in our programs.

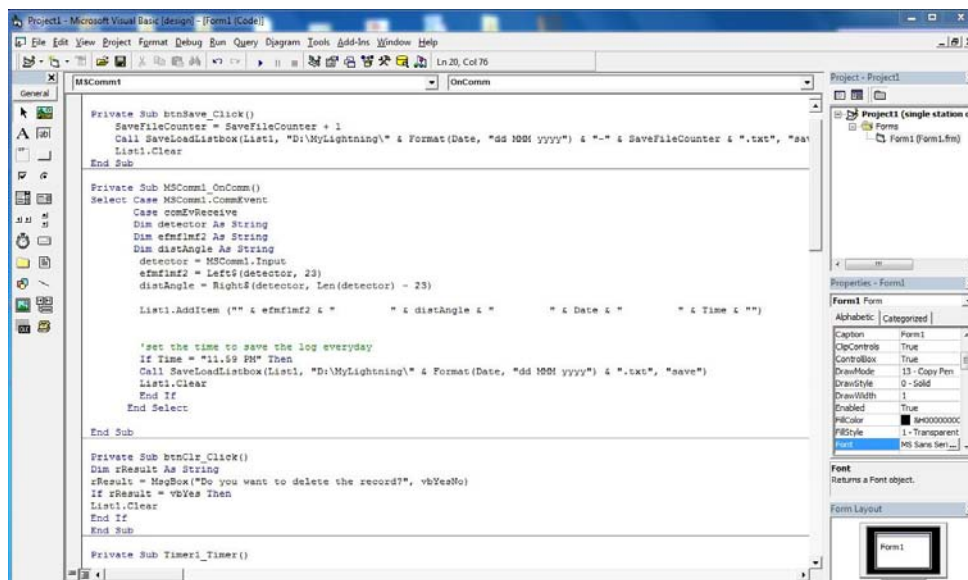


Figure 3.20: Example of Code in VB 6

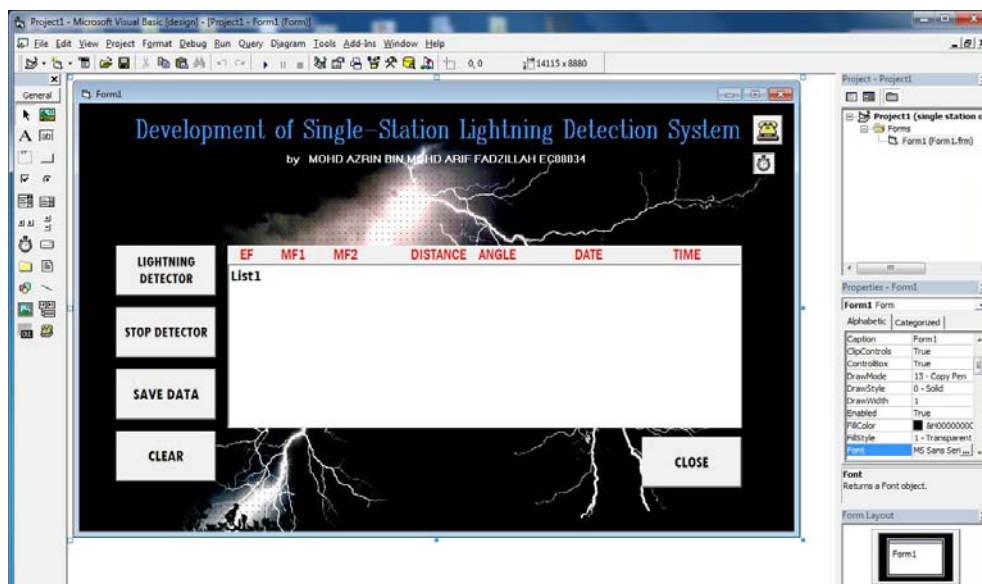


Figure 3.21: Example of Object in VB 6

3.4.3 Proteus

PROTEUS VSM brings you the best of both worlds. It combines a superb mixed mode circuit simulator based on the industry standard SPICE3F5 with animated component models. And it provides an architecture in which additional animated models may be created by anyone, including end users. Indeed, many types of animated model can be produced without resort to coding. Consequently PROTEUS VSM allows professional engineers to run interactive simulations of real designs, and to reap the rewards of this approach to circuit simulation.

And then, if that were not enough, we have created a range of simulator models for popular micro-controllers and a set of animated models for related peripheral devices such as LED and LCD displays, keypads, an RS232 terminal and more. Suddenly it is possible to simulate complete micro-controller systems and thus to develop the software for them without access to a physical prototype. In a world where time to market is becoming more and more important this is a real advantage.

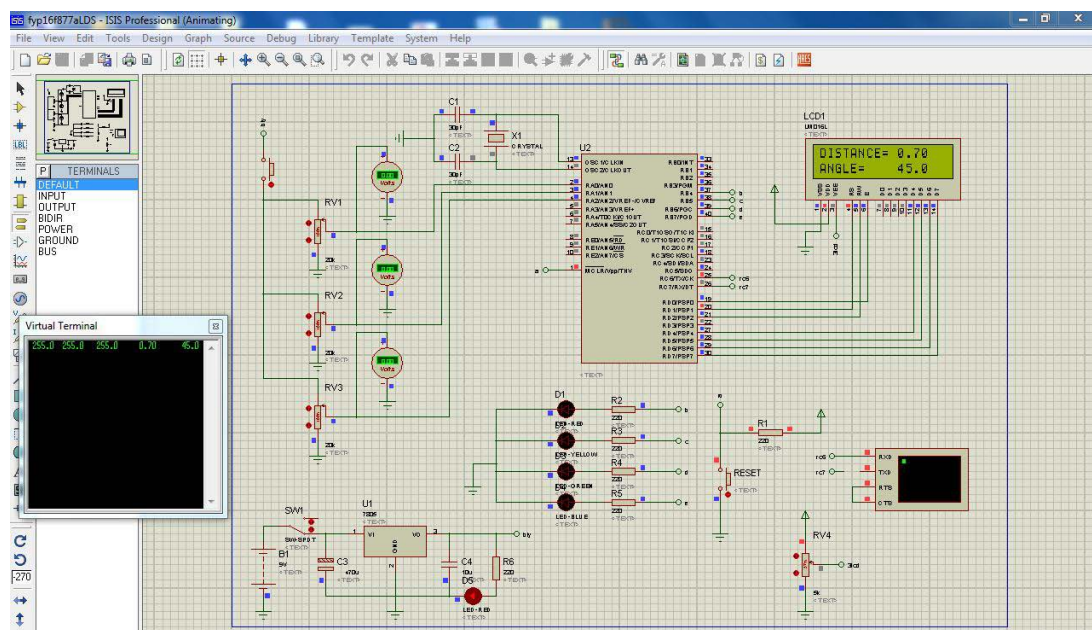


Figure 3.22: Simulation in Proteus

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 Introduction

This chapter describes the results obtained from the implementation of the project. Discussion of this project also included in this chapter. Figure 4.1 is the hardware development of the project. This figure has describes the overall of the project for the Development of Single Station Lightning Detection System.



Figure 4.1: The hardware of the project

4.2 LED Output

The striking of lightning from cloud to the ground generated electrostatic field and electromagnetic field. In this project, the use of variable resistor as virtual input of lightning strike. LED will blinking in a synchronize form when lightning strike happened. In this circuit, the function of push button as acting like lightning strike. If three times push button were pressed, that's mean three times of lightning stroke in that area. So, LED will blink three times.

4.3 LCD Output

LCD will display the result of distance and direction of lightning strike. The calculation of distance and direction written in PIC microcontroller. If the values of electric field and magnetic field for loop 1 and 2 is higher than 0, the data are displayed at LCD. Figure 4.2 below shows the output for PIC microcontroller.

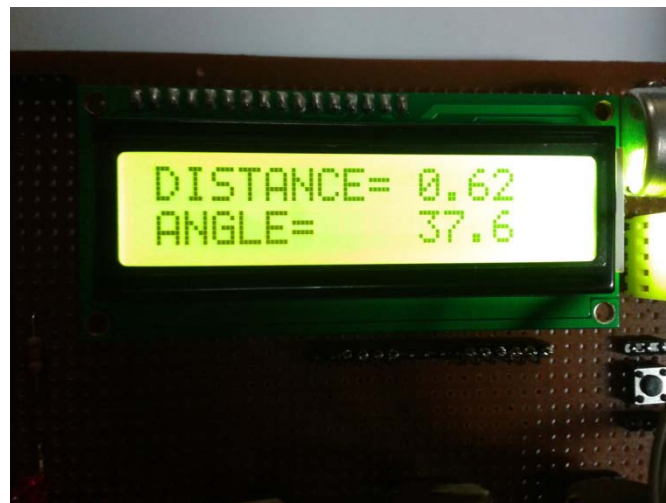


Figure 4.2: The output displayed at the LCD

4.4 Data Recorded in GUI

The lightning detector must be interfaces with the GUI to display the data in listbox that created in Microsoft Visual Basic 6 (VB6). UC00A is a medium to transfer data from PIC microcontroller to the laptop. Same as LED and LCD, when the push button(lightning strike) is pressed, PIC microcontroller will read adc and perform some calculation to get the values of electric field, magnetic field, distance and direction of lightning strike. All the values will appear in VB6 with add on date and time lightning strike detected. In VB6, author created many button such as

lightning detector, stop detector, clear, save data and etc. The user can save the data manually into the laptop when the ‘save data’ button is pressed. The data also will automatically save to the laptop every night on 23.59. All the data would be saved as .txt file.

The important thing to ensure the project is success are the baud rate and COMPORT values for both GUI and lightning detector must be same. If not, the data will not display in listbox VB 6. The code that written in PIC microcontroller also the important aspect in this project. The wrong code written cause of PIC microcontroller is not working as needed. The different of PIC microcontroller must be different code that we must study first. Figure 4.3 shows the main menu in GUI of Single Station of Lightning Detection System. Data is recorded in GUI as shown in Figure 4.4. The source code for GUI is shown in Appendix C.

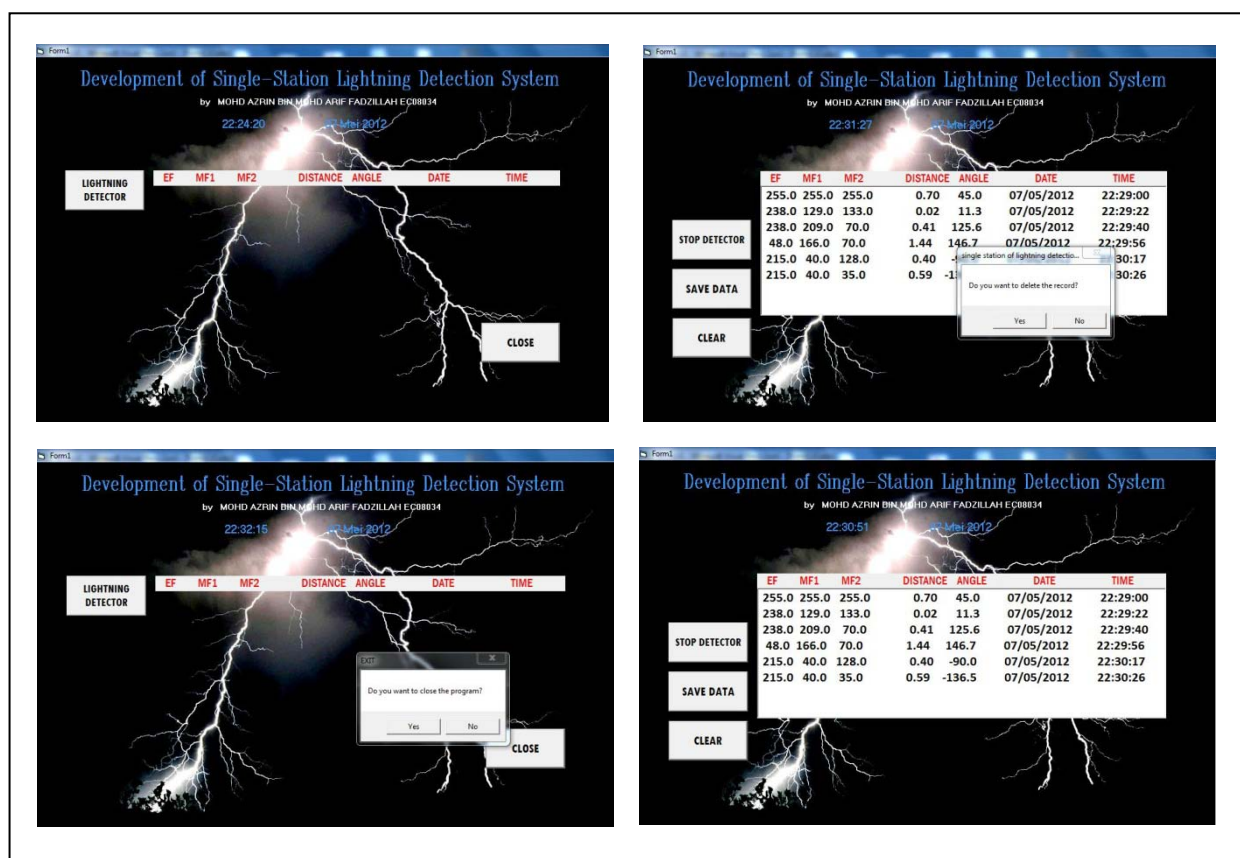


Figure 4.3: Main menu of GUI

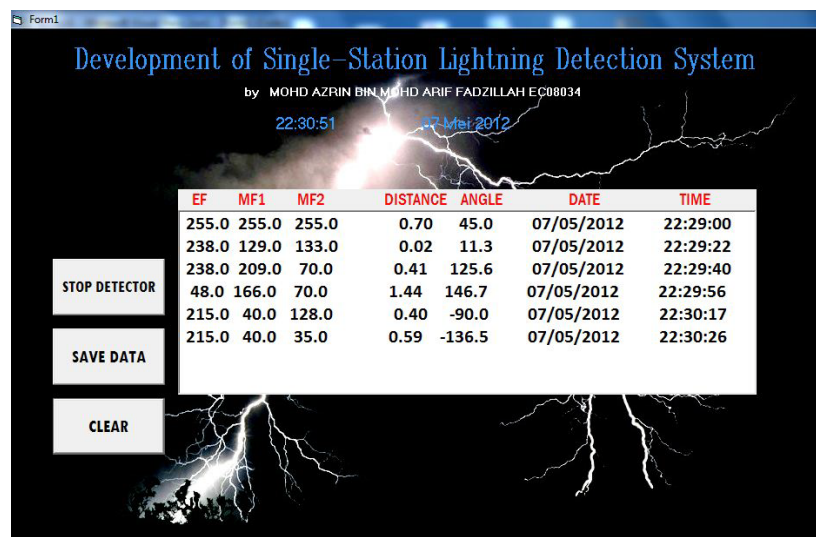


Figure 4.4: Data recorded in GUI

After the data recorded and displayed in GUI, it have to be saved into laptop for future. The data saved as shown in Figure 4.5 below.

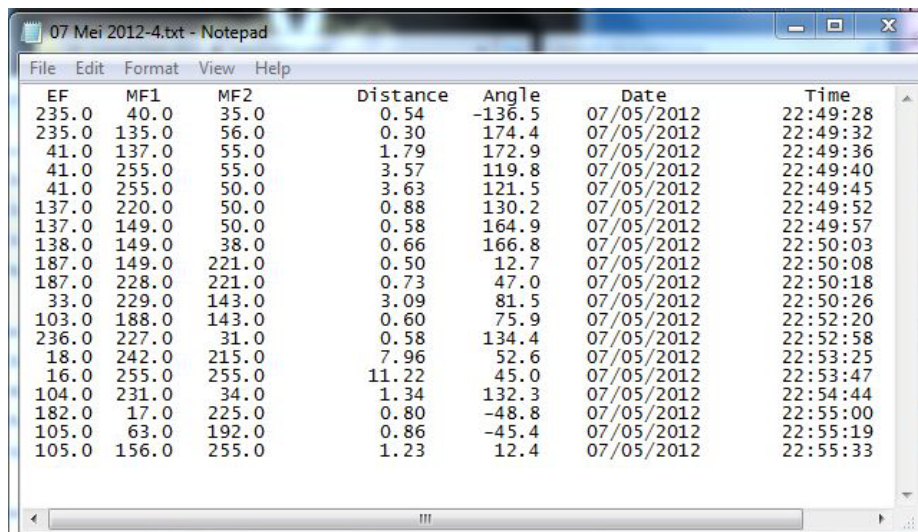


Figure 4.5: Data save as .txt file

4.5 Results Analysis

To observe and analysis the data calculated by PIC microcontroller, few experiments have been carried out and data display in GUI and Proteus simulation were compared. The each result obtained were discussed and explain. Figure 4.6 until figure 4.9 are the result from simulation using Proteus. Meanwhile, Figure 4.10 is the result obtained in GUI from interfacing the lightning detector with the laptop.

EF	MF1	MF2	DISTANCE	DIRECTION
Virtual Terminal				
10.0	10.0	10.0	16.68	-135.0
10.0	10.0	99.0	12.15	-103.8
10.0	10.0	199.0	13.77	-58.9
10.0	10.0	255.0	17.33	-42.8
10.0	99.0	10.0	12.15	-166.1
10.0	99.0	99.0	4.10	-135.0
10.0	99.0	199.0	7.66	-22.2
10.0	99.0	255.0	13.02	-12.8
10.0	199.0	99.0	7.66	112.2
10.0	199.0	199.0	10.04	45.0
10.0	199.0	255.0	14.54	29.2
10.0	255.0	10.0	17.33	132.8
10.0	255.0	99.0	13.02	102.8
10.0	255.0	199.0	14.54	60.7
10.0	255.0	255.0	17.96	45.0

Figure 4.6: Data obtained from PIC where EF= 10 using Proteus

EF	MF1	MF2	DISTANCE	DIRECTION
Virtual Terminal				
99.0	10.0	10.0	1.68	-135.0
99.0	10.0	99.0	1.22	-103.8
99.0	10.0	199.0	1.39	-58.9
99.0	10.0	255.0	1.75	-42.8
99.0	99.0	10.0	1.22	-166.1
99.0	99.0	99.0	0.41	-135.0
99.0	99.0	199.0	0.77	-22.2
99.0	99.0	255.0	1.31	-12.8
99.0	199.0	10.0	1.39	148.9
99.0	199.0	99.0	0.77	112.2
99.0	199.0	199.0	1.01	45.0
99.0	199.0	255.0	1.46	29.2
99.0	255.0	10.0	1.75	132.8
99.0	255.0	99.0	1.31	102.8
99.0	255.0	199.0	1.46	60.7
99.0	255.0	255.0	1.81	45.0

Figure 4.7: Data obtained from PIC where EF= 99 using Proteus

EF	MF1	MF2	DISTANCE	DIRECTION
Virtual Terminal				
199.0	10.0	10.0	0.83	-135.0
199.0	10.0	99.0	0.61	-103.8
199.0	10.0	199.0	0.69	-58.9
199.0	10.0	255.0	0.87	-42.8
199.0	99.0	10.0	0.61	-166.1
199.0	99.0	99.0	0.20	-135.0
199.0	99.0	199.0	0.38	-22.2
199.0	99.0	255.0	0.65	-12.8
199.0	199.0	10.0	0.69	148.9
199.0	199.0	99.0	0.38	112.2
199.0	199.0	199.0	0.50	45.0
199.0	199.0	255.0	0.73	29.2
199.0	255.0	10.0	0.87	132.8
199.0	255.0	99.0	0.65	102.8
199.0	255.0	199.0	0.73	60.7
199.0	255.0	255.0	0.90	45.0

Figure 4.8: Data obtained from PIC where EF= 199 using Proteus

EF	MF1	MF2	DISTANCE	DIRECTION
Virtual Terminal				
255.0	10.0	10.0	0.65	-135.0
255.0	10.0	99.0	0.47	-103.8
255.0	10.0	199.0	0.54	-58.9
255.0	10.0	255.0	0.67	-42.8
255.0	99.0	10.0	0.47	-166.1
255.0	99.0	99.0	0.16	-135.0
255.0	99.0	199.0	0.30	-22.2
255.0	99.0	255.0	0.51	-12.8
255.0	199.0	10.0	0.54	148.9
255.0	199.0	99.0	0.30	112.2
255.0	199.0	199.0	0.39	45.0
255.0	199.0	255.0	0.57	29.2
255.0	255.0	10.0	0.67	132.8
255.0	255.0	99.0	0.51	102.8
255.0	255.0	199.0	0.57	60.7
255.0	255.0	255.0	0.70	45.0

Figure 4.9: Data obtained from PIC where EF= 255 using Proteus

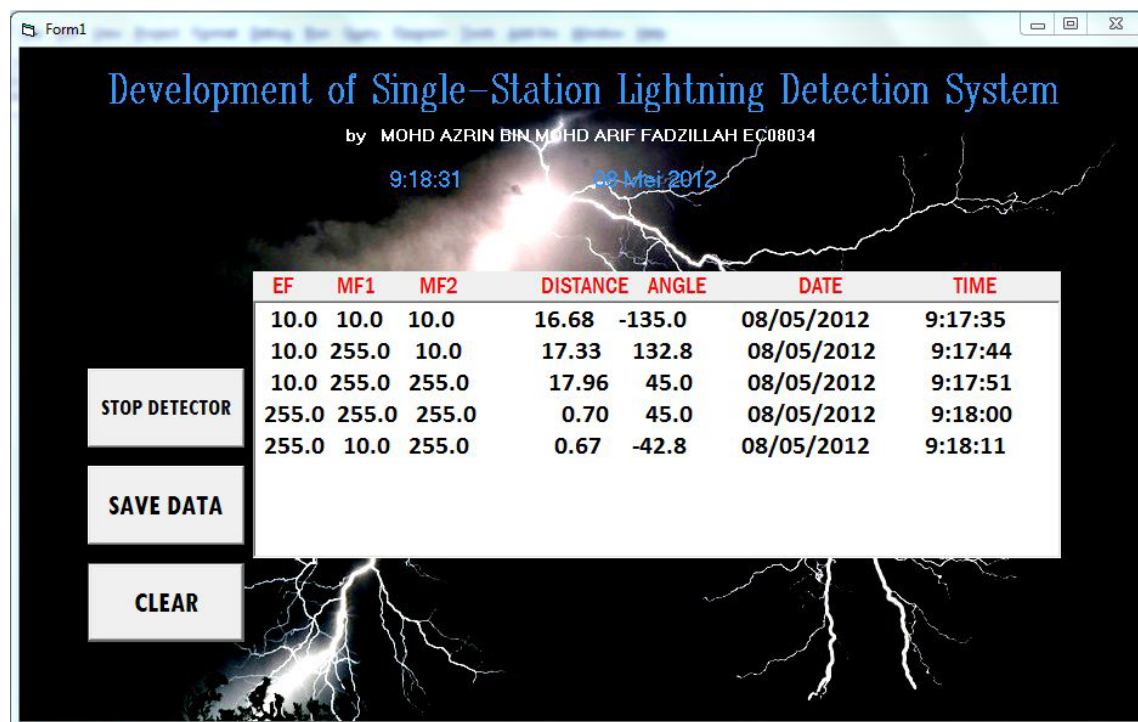


Figure 4.10: Data obtained from PIC where EF= 10, 255 using VB6

From the results in Proteus and GUI above, the data both is matched. So, the connection in hardware implementation is correct. Note that, the decreasing values of electric field mean the distance of lightning strike occur far away from the antenna. This shown when comparing two values of electric field, 10 and 255. For EF= 10, the distance of lightning strike is equal 16.68 while EF=255, the distance of lightning strike is equal 0.67. The conclusion is the higher value of electric field, the distance of lightning strike from the antenna is increase. This is a safe situation for that area.

From the data direction, the angle will negative if magnetic field for loop 1 is equal 10 meanwhile will be positive if magnetic field for loop 1 is equal 255. Values of electric field not effected to the direction of lightning strike because in the formula produce by previous researcher to find the direction of lightning not included EF.

4.6 Discussions

The target of this project is to develop a lightning detector together with antennas to sense the electric field and magnetic field produced by the lightning. To achieve the desired target, the virtual inputs have been produced to simulate the performance of lightning detector.

The results obtained from PIC microcontroller are calculated based on virtual inputs generated. These virtual inputs are generated from three variable resistor connected to three analog input pin of PIC microcontroller. Hence, data of electric field, magnetic field, distance and direction obtained are not representing the signal of lightning strike. Mean, the distance and direction obtained not the real distance and direction of lightning strike.

One wire antenna and a pair of loop antenna for lightning detector is required to further justify the performance of lightning detector of single station developed. The result then will compare with this simulation result of lightning strike. Development of that antenna that suitable for this project required more time to do the research and apply it. Length of antenna also will be measured causes this affected to distance of lightning can detects. So it should carry out in future as an improvement to this project.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Limitations

There are many problems in completing this project such as PIC microcontroller not working as needed. It's like not functioning because LED not blink, data not display in LCD and no output from PIC microcontroller display in listbox created in VB 6. After many research, finally, author detected that each type of PIC microcontroller have their own code to make it function. PIC microcontroller is a complicated device. So, user need understand of its peripheral and application.

Second, the problem interfacing between PIC microcontroller with laptop. The calculated data from PIC16F877A will send to GUI through UC00A. The problem happened when the COMPORT and baud rate not matched between each other. As example, the coding in PIC microcontroller is 2400 baud rate and GUI is 9600 baud rate, it cause of no connection interface. So, the result not displayed in GUI created. User have the problem to analyze the data of lightning strike happened in that area.

Besides, one of the problem data in GUI not displayed cause of wrong coding in VB6. Author make a lot of research to ensure this project succeed. As example the function of "Left\$(string, length), MSComm1_OnComm, MSComm1.RThreshold, MSComm1.InputLen, MSComm1.Input and etc" . All the code written must be declared so that GUI will run to interface with the hardware. It is time consuming to detect the error.

Lastly, port in the laptop for UC00A not install yet. So, UC00A installation guide is the important note to read carefully. Each operating system such as Window 7, Window Vista and Window XP have their own way to install the port. The problem that occurred to after check the port that used, GUI still not function. Author identify that problem and decide to adjust the com port from COM38 to COM2. Finally, the result of lightning strike including of date and time displayed in listbox. All the button function well.

5.2 Recommendations

This project is only simulation of lightning strike using variable resistor as virtual input. The reason why not used of the real antenna cause of not have the suitable antenna to conduct this project. Author focused on the input that fed to analog pin PIC microcontroller and the software that used to make it this project finish and complete. Antenna to detect the real lightning as the improvement of this project for future work. Some of the changes that should be made to produce better and improved project are such as:

- i. Use the buzzer to warning if lightning strike occurred.
- ii. Using bluetooth technology as a medium for transferring the data from the hardware to the GUI.

5.3 Conclusion

The project of lightning detector is successfully done. Electric field and magnetic field strength are the important aspect to know how far lightning strike happened from the antenna. All the data are able to transfer to the LCD and laptop. Based on the circuit construct and the results obtained, this project has achieved the objective.

REFERENCES

- [1] Koay Kim Leong (2009). *Lightning Strike Distance Detector*. Bachelor Degree, Universiti Teknologi Malaysia, Skudai.
- [2] Yagitani, S., Nagano, I., and Ozaki M. (2006). Lightning Detection System with Sferics Observation at a Single Station. *28th International Conference on Lightning Protection*. Kanazawa University
- [3] Ibrahim, W. I., and Malek, Z. A. (2010). Time-to-Thunder Method of LightningDistance Determination. *IEEE InternationalConference on Power and Energy*, pg357-360
- [4] Ruhnke, L. H. (1973). *US Patent No 3715660*. Retrieved on March 7, 2012, from www.ptodirect.com
- [5] Mackay, C., and A. C. Fraser Smith (2011), World coverage for single station lightning detection, *Radio Sci.*, 46, RS0M01.
- [6] Cooray, V., Rakov, V., and Theethayi, N. (2006), Lightning striking distance , *Jurnal of Electrostatics*, 65, 296-306

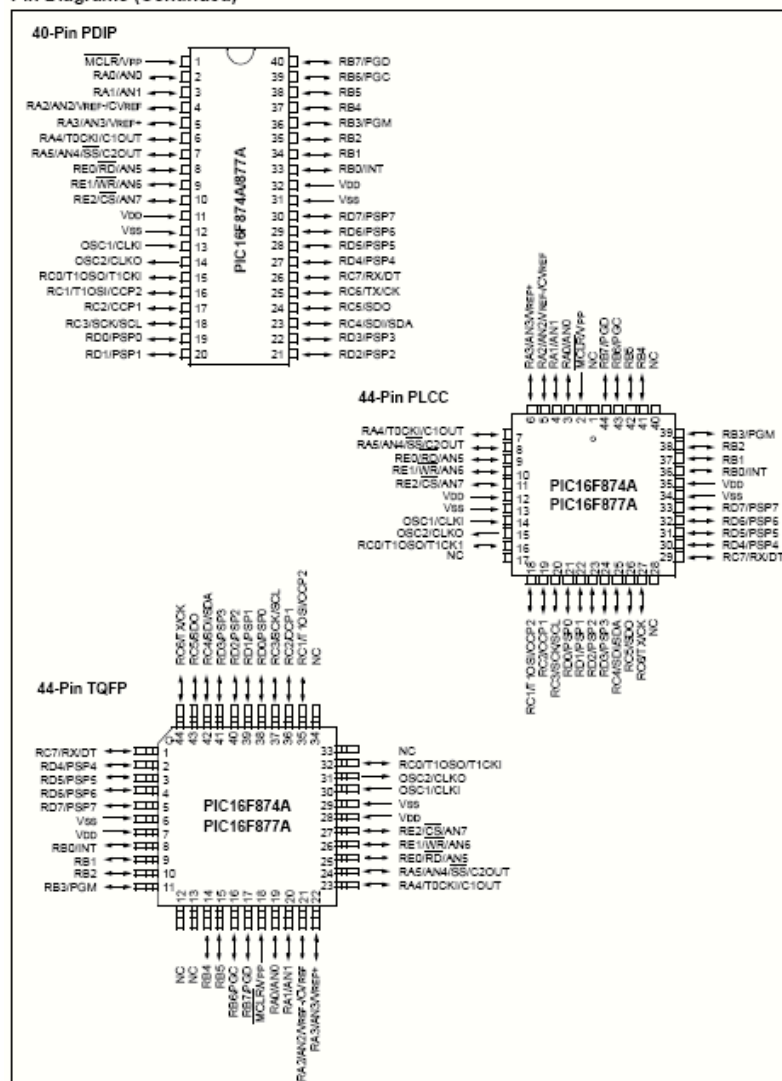
- [7] Ruhnke, L. H. (1962). Distances of lightning strokes as determined from electrostatic field strength measurements, *Jurnal of Applied Meteorology*, 1, 544-547.
- [8] Nik NorHadi Bin Abu Hassan (2004), *Lightning Detector*, Bachelor Degree, Universiti Teknologi Malaysia, Skudai.
- [9] Markson, R. J., and Ruhnke, L. H. (2001). *US Patent No6246367*.Retreived on March 7, 2012, from www.ptodirect.com.
- [19] Yahya, M. P.(2007). Lightning phenomena in Malaysia, *Seminar for ARSEPE'07*. 8-15 January, Universiti Tenaga Nasional
- [11] Wiolland, K. (2005), Lightning Detection,*Avionic News*
- [12] Rafalsky, V. A., Nickolaenko, A. P., Shvets, A. V., and Hayakawa, M. "Location of lightning discharges from a single station," *J. Geophys. Res.*, vol. 100, no. D10, pp. 20829-20838,Oct. 1995.
- [13] Brundell, J. B., Rodger, C. J., and Dowden, R. L. Validation ofsingle-station lightning location technique, *Radio Sci.*, vol. 37, no.4, 2002.

APPENDIX A

DATASHEET OF PIC16F87XA

PIC16F87XA

Pin Diagrams (Continued)



Appendix B

Program Code for PIC16F877A

```

/////////////////////////////////////////////////////////////////
//                                                                    //
//      DEVELOPMENT OF SINGLE-STATION                                //
//      LIGHTNING DETECTION SYSTEM                                  //
//                                                                    //
//      Written by Mohd Azrin Bin Mohd Arif Fadzillah                //
//                                                                    //
/////////////////////////////////////////////////////////////////

//all these # below set up the PIC
#include <16F877A.h>
#define adc=8
#define FUSES NOWDT //No Watch Dog Timer
#define FUSES HS //Highspeed Osc > 4mhz
#define FUSES NOPUT //No Power Up Timer
#define FUSES NOPROTECT //Code not protected from reading
#define FUSES NODEBUG //No Debug mode for ICD
#define FUSES NOBROWNOUT//No brownout reset
#define FUSES NOLVP //No low voltage prgming, B3(PIC16) or
                    B5(PIC18) used for I/O
#define FUSES NOCPD //No EE protection
#define use delay(clock=20000000)
//crystal oscillator at 20000000 hertz

```

```

#use rs232(baud=9600,parity=N,xmit=PIN_C6,rcv=PIN_C7,bits=8,TIMEOUT=1)
//serial port output pin & baud rate
#include <lcd.c>           // LCD DISPLAY HEADER FILE
#include <math.h>
#include <float.h>

/////////////////////////////////////////////////////////////////
//                                                                    //
//              I/O DECLARATION  //              //
//                                                                    //
/////////////////////////////////////////////////////////////////

/////////////////////////////////////////////////////////////////
//                                                                    //
//              LED  //              //
//                                                                    //
/////////////////////////////////////////////////////////////////

#define LED1 PIN_B4        // LED 1
#define LED2 PIN_B5        // LED 2
#define LED3 PIN_B6        // LED 3
#define LED4 PIN_B7        // LED 4

/////////////////////////////////////////////////////////////////
//                                                                    //
//              ANALOG INPUT  //              //
//                                                                    //
/////////////////////////////////////////////////////////////////

#define VR_ELEC PIN_A0      // VARIABLE RESISTOR FOR ELECTRIC
                           FIELD
#define VR_MAG1 PIN_A1      // VARIABLE RESISTOR FOR MAGNETIC
                           FIELD 1

```

```

#define VR_MAG2 PIN_A2          // VARIABLE RESISTOR FOR MAGNETIC
                                FIELD 2

/////////////////////////////////////////////////////////////////
//                                                                    //
//          LCD DISPLAY      //          //
//                                                                    //
/////////////////////////////////////////////////////////////////

#define LCD_E PIN_D0           // PIN E
#define LCD_RS PIN_D1          // PIN RS
#define LCD_RW PIN_D2          // PIN RW
#define LCD_D4 PIN_D4          // PIN D4
#define LCD_D5 PIN_D5          // PIN D5
#define LCD_D6 PIN_D6          // PIN D6
#define LCD_D7 PIN_D7          // PIN D7

/////////////////////////////////////////////////////////////////

void main()
{

/////////////////////////////////////////////////////////////////
//                                                                    //
//          LOCAL VARIABLE          //          //
//                                                                    //
/////////////////////////////////////////////////////////////////

int32 elec;
int32 mag1;
int32 mag2;
float distance;
float angle;
float pow_mag1;

```



```

delay_ms(200);

set_adc_channel(0);          // POINTS ADC AT CHANNEL 0 (AN0)
delay_us(10);                // DELAY TO GET ANALOG VALUE
elec=read_adc();             // READ ANALOG INPUT 1(ELECTRIC FIELD)

set_adc_channel(1);          // POINTS ADC AT CHANNEL 1 (AN1)
delay_us(10);                // DELAY TO GET ANALOG VALUE
mag1=read_adc();             // READ ANALOG INPUT 2(MAGNETIC FIELD 1)

set_adc_channel(2);          // POINTS ADC AT CHANNEL 2 (AN2)
delay_us(10);                // DELAY TO GET ANALOG VALUE
mag2=read_adc();             // READ ANALOG INPUT 3(MAGNETIC FIELD 2)

if(elec>0 && mag1>0 && mag2>0)

{
    pow_mag1=((float)mag1-128)*((float)mag1-128);
    pow_mag2=((float)mag2-128)*((float)mag2-128);

    distance=sqrt(pow_mag1+pow_mag2)/((float)elec);
    angle=atan2((float)mag1-128,(float)mag2-128);
    angle=angle*180/3.14159;

    printf(lcd_putc,"\fDISTANCE= %4.2f", (float)distance);
    // DISPLAY DISTANCE AT LCD DISPLAY
    printf(lcd_putc,"\nANGLE= %7.1f", (float)angle);
    // DISPLAY ANGLE AT LCD DISPLAY

    printf("%6.1f%7.1f%8.1f%9.2f%10.1f\r\n", (float)elec, (float)mag1, (float)mag2, (float)
    )distance, (float)angle);

```

```
output_high(LED1);  
delay_ms(50);  
output_low(LED1);
```

```
output_high(LED2);  
delay_ms(100);  
output_low(LED2);
```

```
output_high(LED3);  
delay_ms(150);  
output_low(LED3);
```

```
output_high(LED4);  
delay_ms(200);  
output_low(LED4);
```

```
}
```

```
}
```

```
}
```

Appendix C

Program Code for GUI

Option Explicit

Dim SaveFileCounter As Integer

Private Sub btnSave_Click()

 SaveFileCounter = SaveFileCounter + 1

 Call SaveLoadListbox(List1, "D:\MyLightning\" & Format(Date, "dd MMM
yyyy") & "-" & SaveFileCounter & ".txt", "save")

 List1.Clear

End Sub

Private Sub MSComm1_OnComm()

Select Case MSComm1.CommEvent

 Case comEvReceive

 Dim detector As String

 Dim efmf1mf2 As String

 Dim distAngle As String

 detector = MSComm1.Input

 efmf1mf2 = Left\$(detector, 23)

 distAngle = Right\$(detector, Len(detector) - 23)

 List1.AddItem (" " & efmf1mf2 & " " & distAngle & " " & Date & "
" & Time & " ")


```
'set the time to save the log everyday
If Time = "11.59 PM" Then
    Call SaveLoadListbox(List1, "D:\MyLightning\" & Format(Date, "dd MMM
yyyy") & ".txt", "save")
    List1.Clear
End If
End Select
```

```
End Sub
```

```
Private Sub btnClr_Click()
Dim rResult As String
rResult = MsgBox("Do you want to delete the record?", vbYesNo)
If rResult = vbYes Then
List1.Clear
End If
End Sub
```

```
Private Sub Timer1_Timer()
Label3.Caption = Time
Label4.Caption = Format(Date, "dd MMM yyyy")
End Sub
```

```
Private Sub btnCls_Click()
Dim rClose As String
rClose = MsgBox("Do you want to close the program?", vbYesNo, "EXIT")
If rClose = vbYes Then
End
End If
End Sub
```

```

Private Sub btnStpD_Click()
    btnStr.Visible = True
    btnClr.Visible = False
    btnStpD.Visible = False
    btnSave.Visible = False
    btnCls.Visible = True
    List1.Visible = False
End Sub

```

```

Private Sub btnStr_Click()
    List1.Visible = True
    btnClr.Visible = True
    btnStpD.Visible = True
    btnStr.Visible = False
    btnSave.Visible = True
    btnCls.Visible = False
    MSComm1.Output = " & lighting & "
    'Fire Rx Event Every One Character
    MSComm1.RThreshold = 42
    'When Inputting Data, Input One Byte at a time
    MSComm1.InputLen = 42
End Sub

```

```

Private Sub SaveLoadListbox(plstLB As ListBox, pstrFileName As String,
    pstrSaveOrLoad As String)
    Dim strListItems As String
    Dim i As Long
    Select Case pstrSaveOrLoad
    Case "save"
        Open pstrFileName For Output As #1
        Print #1, " EF    MF1    MF2          Distance  Angle    Date    Time    "
        For i = 0 To plstLB.ListCount - 1
            plstLB.Selected(i) = True

```

```
Print #1, plstLB.List(plstLB.ListIndex)
Next
Close #1
List1.Clear
Case "load"
plstLB.Clear
Open pstrFileName For Input As #1
While Not EOF(1)
Line Input #1, strListItems
plstLB.AddItem strListItems
Wend
Close #1
End Select
End Sub
```

```
Private Sub Form_Load()
List1.Visible = False
btnStpD.Visible = False
btnClr.Visible = False
btnSave.Visible = False
SaveFileCounter = 0
MSComm1.CommPort = 2
'9600 baud, no parity, 8 data bits, 1 stop bit
MSComm1.Settings = "9600,N,8,1"
'Open the port
MSComm1.PortOpen = True
End Sub
```

```
Private Sub Form_Unload(Cancel As Integer)
'Close the port
MSComm1.PortOpen = False
End Sub
```

Appendix D

Schematic Diagram of Single Station Lightning Detection System

