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JUDUL: **DEVELOPMENT OF DIGITAL WIND SPEED METER WITH WIND DIRECTION**

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DEVELOPMENT OF DIGITAL WIND SPEED METER WITH WIND DIRECTION

MOHD MOKHTAR BIN ISMAIL

A report submitted in partial fulfilment of the
requirements for the award of the degree of
Bachelor of Electrical Engineering (Control and Instrumentation)

Faculty of Electrical & Electronic
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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 (Control and Instrumentation)"

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Date : ______________________________

Dedicated to my dearest friend, whom without her,
I am nowhere near who I am now.

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May Allah reward His peace and blessings to all of you, and may this work brings benefit to the mankind.

ABSTRACT

An aerovane is one of the devices that is used to measure wind speed and direction. The wind speed measured using aerovane is much more acurate as it measures the speed of the wind which parallel to the wind direction. This project mainly focuses on using microcontroller PIC 16F877A to control the circuit and building the aerovane type wind vane model. Hall Effect sensor is used for speed measurement and 10kΩ potentiometer for direction detection. The sensor resolution for speed measurement is one pulse per rotation. For direction, the specific direction is determined at every 45° rotation of potentiometer. The microcontroller is used as a central contoller to measure the speed and direction of the wind and displays it on a 16 x 2 characters LCD. From the measured pulse per minute, the speed is calibrated for displaying the value in km/h. While the direction will be display in specific direction which is North, NorthEast, East, SouthEast, South, SouthWest, West, and NorthWest. Based on the output, the PIC 16F877A can be an ideal microcontroller for developing this project. However, the aerovane modelling should be done in more accurate manner to get more accurate wind measurement.

ABSTRAK

Kincir angin adalah merupakan salah satu alat yang digunakan untuk mengukur kelajuan dan arah angin. Kelajuan angin yang diukur oleh kincir angin adalah lebih tepat kerana ia mengukur angin yang selari dengan arahnya. Projek ini menumpu kepada menggunakan mikropengawal PIC 16F877A untuk mengawal litar dan membina model pengukur angin jenis kincir angin. Pengesan kesan Hall digunakan untuk mengukur kelajuan angin dan perintang boleh laras 10kΩ digunakan untuk mengukur arah. Resolusi pengesan kelajuan adalah satu denyut per pusingan. Untuk pengukur arah, arah tententu ditentukan setiap 45° pusingan oleh perintang boleh laras. Mikropengawal digunakan sebagai pengawal pusat untuk mengukur kelajuan dan arah angin dan memaparkannya pada 16 x 2 abjad LCD. Melalui denyut per minit yang telah diukur, nilai yang diperolehi akan disesuaikan untuk memaparkan nilai kelajuan angin dalam unit km/j. Arah angin pula akan dipaparkan dalam arah khusus iaitu Utara, Timur Laut, Timur, Tenggara, Selatan, Barat Daya, Barat, dan Barat Laut. Berdasarkan keluaran yang diperoleh, mikropengawal PIC 16F877A boleh menjadi mikropengawal yang ideal untuk membangunkan projek ini. Namun, pemodelan kincir angin perlu dilakukan dengan lebih terperinci untuk mendapatkan pengukuran angin yang lebih tepat.

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LIST OF SYMBOLS

°	-	Degree
s	-	Second
V	-	Voltage
GND	-	Ground
B_{OP}	-	Magnetic flux density operating point threshold
B_{RP}	-	Magnetic flux density release point threshold
B_{hys}	-	Magnetic flux density hysteresis
Ω	-	Ohm
F	-	Farad
km/h	-	Kilometer per hour
rpm	-	Rotation per minute
rps	-	Rotation per second
Hz	-	Hertz
m	-	Meter
A	-	Ampere

LIST OF ABBREVIATIONS

LCD	-	Liquid Crystal Display
N	-	North
S	-	South
E	-	East
W	-	West
NE	-	North East
SE	-	South East
SW	-	South West
NW	-	North West
I/O	-	Input or Output
ADC	-	Analog-to-digital converter
OSC	-	Oscillator

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CHAPTER 1

INTRODUCTION

1.1 Background

Weather measurement tools are important for human beings, used to determine the actual weather and forecasting, and wind is one of the weather elements that can be measured. It is a known fact that wind really influences our daily life. Good and even bad situations can be caused by wind. Wind brings rain from one place to another; cools down hot areas, and at some windy areas, wind can be used to generate electrical power. However, it can also bring disasters, such heavy rain which is very dangerous for people driving vehicles on the road, and not to mention, storm and hurricane which are capable of producing mass catastrophe. With the advancements in technology nowadays, measuring weather - especially wind, is made easily done and accurate since it can improve our quality of life.

Wind measurement tools are termed “Anemometer”. An anemometer is a device for measuring the velocity or the pressure of the wind, and is one of the instruments used in weather stations. The term is derived from the Greek word "anemos" meaning wind. There are six types of velocity anemometer [1];

1. Cup anemometers
2. Hot-wire anemometers
3. Laser Doppler anemometers
4. Sonic anemometers
5. Windmill anemometers

6. MEMS anemometers

In some instruments, wind speed measurement is not practiced. For example, in a wind direction tool called windsock. A windsock is a large, conical tube designed to indicate wind direction and relative wind speed. Windsocks typically are used in airports and in chemical plants in which there are risks of gaseous leakage. They are sometimes located alongside highways at windy locations. However, it does not show the magnitude of the wind speed. For better weather forecast, analysis and respond, a combination of wind speed and wind direction measurement is needed.

1.2 Objective of Project

The main core of this project is to design a wind measurement instrument for measuring wind speed and direction using a microcontroller. This system will display the current speed and direction of the wind on LCD.

1.3 Scope of Project

In order to achieve the objective of the project, several scopes have been outlined. The scope of this project are; using microcontroller PIC 16F877A for controlling the circuit, using hall effect sensor for speed measurement in RPM, using potentiometer for wind direction measurement (output is given in analog signal) and using LCD 16 characters, 2 lines for displaying the value of measured wind speed and direction. Besides that, the scope also includes building a working Aerovane model to be applied together with the wind speed and direction sensor.

1.4 Summary of Project

Implementation and works of the project are summarized into Figure 1.0 and Figure 1.1. Gantt charts as shown in Figure 1.2 and Figure 1.3 show the detail of the works of the project that has been implemented in the first and second semester.

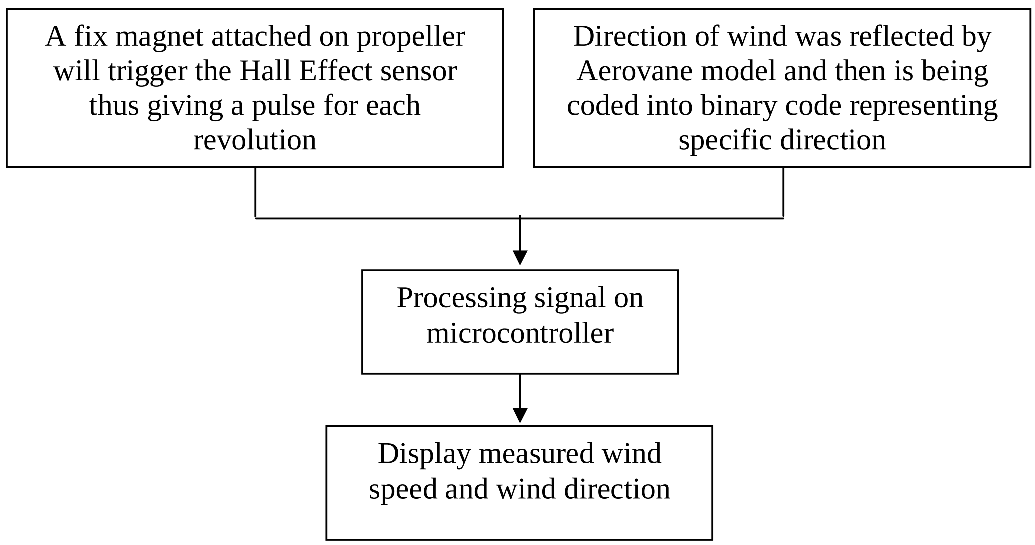


Figure 1.1 Block Diagram

Description:

A fix magnet is attached onto the Aerovane propeller. When the wind blows, the propeller will spin relative with the wind speed, thus the magnet will trigger the Hall Effect sensor. A pulse will be generated as an output for each revolution. The time difference from each pulse is used to calculate the speed of the wind.

At the same time, the tail of the Aerovane will direct according to wind direction. The Aerovane is attached with potentiometer which will give analog signal output with respect to the direction of the wind. The analog signal is being converted into 8-bit binary by the analog to digital converter module in microcontroller.

The output from Hall Effect sensor and potentiometer will be transmitted to microcontroller to be processed and calculated.

The calculated measurement will be displayed on the LCD. The LCD used is the 16 characters and 2 lines type. It will be displaying the speed of the wind in km/h unit with the direction of the wind in a specific direction.

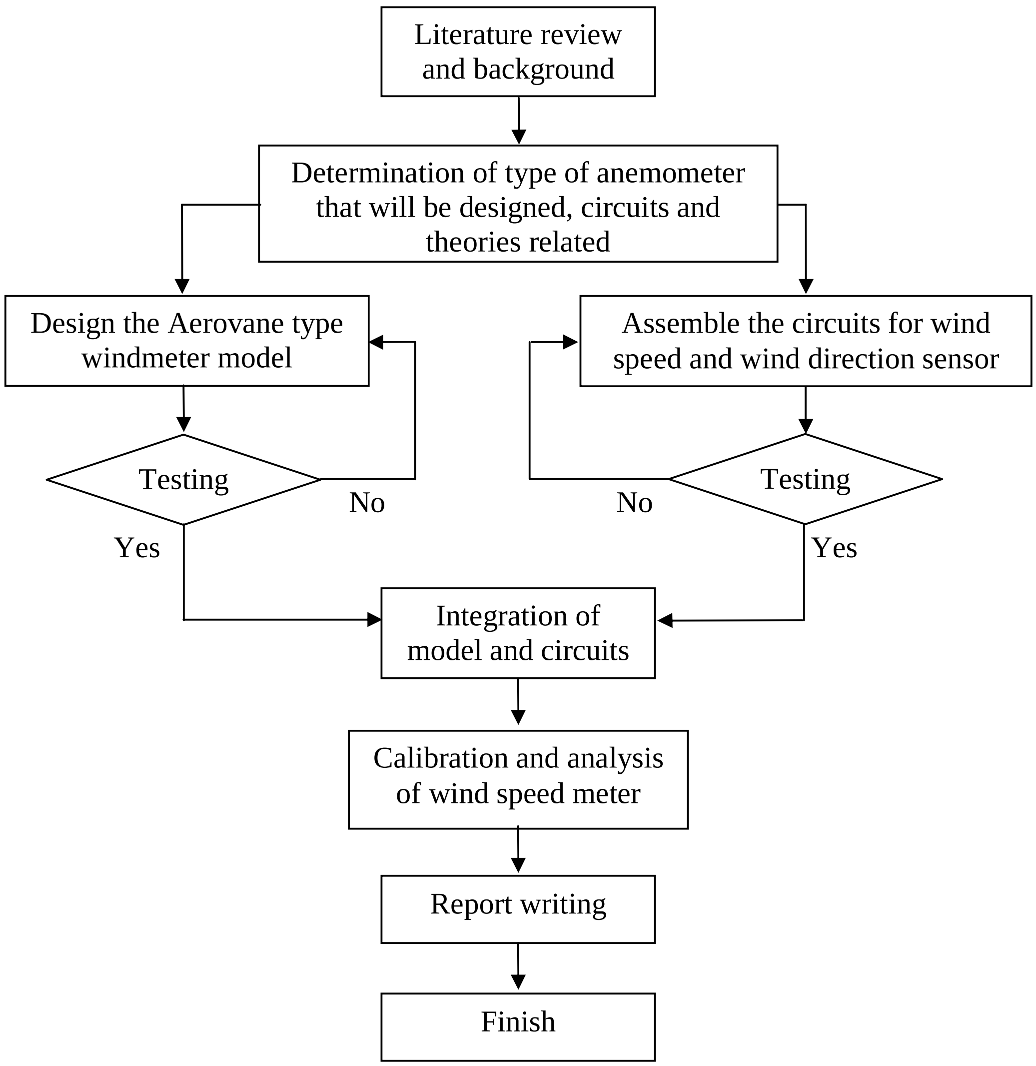


Figure 1.2 Flow of development

Description:

Literature review and research on theories related to the project begins after the title of the project was decided. These involve theories such as Hall Effect sensor, rotary encoder, potentiometer, anemometer, microcontroller and a few others. By obtaining most of the information from the internet and a few reference book, the Aerovane type was chosen to be developed in this project because it has both speed and direction measurement.

The project is divided into two parts; the modeling and the circuit. The modeling part involves developing a model of the Aerovane which has three main components; body, tail, and propeller. The body can move from right to left and back, and spin around according to the direction of the wind. It is supported by the tail. The propeller is the part where the Hall Effect sensor is attached. It will spin relative with wind speed.

The design (i.e. size, shape and weight) of the propeller is important to ensure a maximum read of wind speed. The main issue here is friction. The model must have as little friction as possible to ensure that the sensor is sensitive and that a more accurate reading is obtained. Using the contact less Hall Effect sensor on propeller and ball bearing on the body is essential.

For the circuit part, a microcontroller is used as the main element because one microcontroller can be programmed to have all the processes required in it. Calculation and providing output on digital display is done by microprocessor. It is cost efficient and flexible in usage. The Hall Effect sensor output can be connected directly to the microcontroller. LCD is used to display the output (speed and direction of wind) after the measurement process.

Integration of both the model and circuit will be done when both parts are ready.

Calibration process is the process of tuning the programming until the accepted speed value in metric unit is obtained. Calibration is needed for displaying the accepted value on the LCD as well as to reduce error.

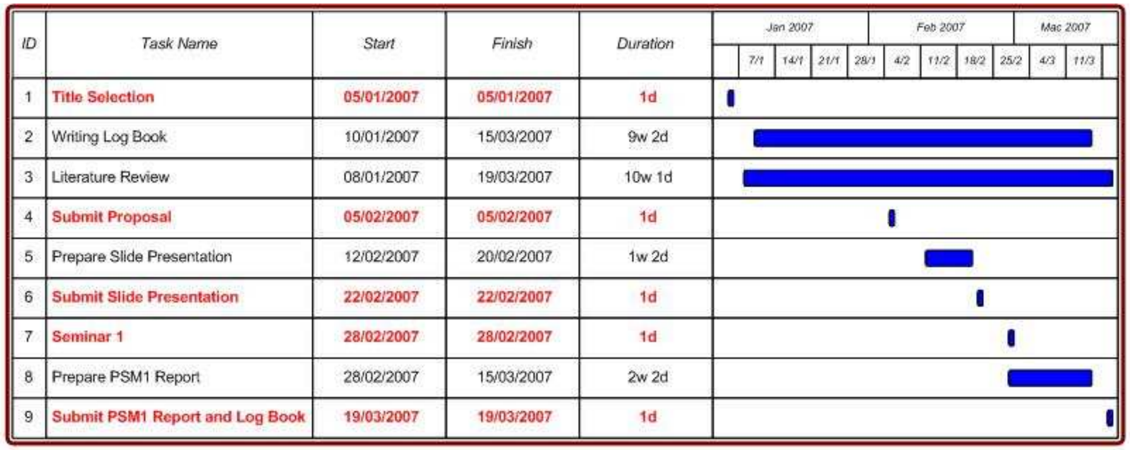


Figure 1.3 Gantt chart of the project schedule for semester 1

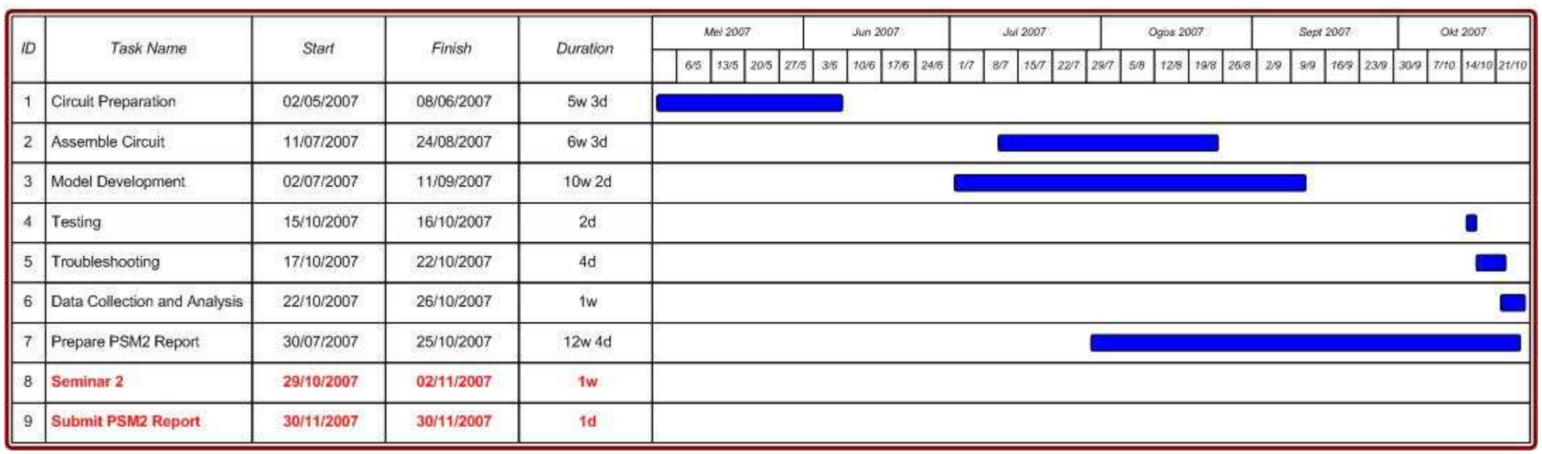


Figure 1.4 Gantt chart of the project schedule for semester 2

CHAPTER 2

THEORY AND LITERATURE REVIEW

2.1 Introduction

This chapter includes the study of wind speed and direction measurement system. The speed of the wind is measured using the Hall Effect sensor whilst for direction measurement, a potentiometer is used. It also touches briefly on microcontrollers, and other relevant hardware used in this project.

2.2 Anemometer

Instruments used to measure wind speed (velocity) is called anemometer. The term ‘anemo’ come from the Greek word, ‘anemos’ meaning wind. Anemometer can be divided into 2 classes: those that measure the velocity of the wind and those that measure the pressure of the wind [1].

For anemometer that measure velocity of the wind, they are divided into 6 types; Cup anemometers, Hot-wire anemometers, Laser Doppler anemometers, sonic anemometers, Windmill anemometers and MEMS anemometers.

2.2.1 Cup Anemometer

Cup anemometer is the simplest type of anemometer. It was invented in 1846 by Dr. John Thomas Romney Robinson, of Armagh Observatory. It consists of three or four hemispherical cups, mounted one on each end of a horizontal arm, which lie at equal angles to each other. A vertical axis round which the cups turn passes through the centre of the arms; flow of air past the cups in any horizontal direction turns the cups in a manner that is proportional to the wind speed. The turns of the cups over a set of time gives the average speed of wind.

The simplicity of cup anemometer makes it popular until now. However, it is not a very good instrument for data logging for any particular moments. It was later discovered that the actual relationship between the speed of the wind speed and that of the cups depends very largely on the dimensions of the cups and arms. Consequently, wind speeds results published in many official 19th century publications were often in error by nearly 60%.

Figure 2.1 Cup Anemometer

2.2.2 Hot-wire Anemometer

Hot-wire anemometers use a very fine wire (on the order of several micrometers) heated up to some temperature above the ambient. Flow past the wire has a cooling effect on the wire. As the electrical resistance of most metals (tungsten is a popular choice for hot-wires) is dependent upon the temperature of the metal, a relationship can be obtained between the resistance of the wire and the flow velocity. Hot-wire anemometers, while extremely delicate, have extremely high frequency-response and fine spatial resolution compared to other measurement methods, and as such are almost universally employed for the detailed study of turbulent flows, or any flow in which rapid velocity fluctuations are of interest.

2.2.3 Laser Doppler Anemometer

Laser Doppler anemometers use a laser that is split and sent out of the anemometer. The backscatter of the laser beam off of air molecules is directed into a detector where the radiation relative to the laser in the anemometer and the backscattered radiation are compared to determine the velocity of the air molecules.

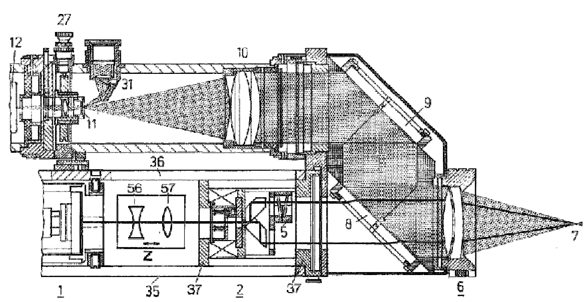


Figure 2.2 Laser Doppler Anemometer

The laser is emitted (1) through the front lens (6) of the anemometer and is backscattered off the air molecules (7). The backscattered radiation (dots) re-enter the device and are reflected and directed into a detector (12).

2.2.4 Sonic Anemometer

Sonic anemometers use ultrasonic sound waves to measure wind speed and direction. They are capable of measuring wind velocity in the X (east-west), Y (north-south), and Z (up-down) directions. The spatial resolution is given by the path length between transducers, which is typically 10 to 20 cm. Sonic anemometers can take measurements with very fine temporal resolution, 20 Hz or better, which make them well suited for turbulence measurements. The lack of moving parts makes them appealing to automated weather stations. Their main disadvantage is the distortion of the flow itself by the structure supporting the six transducers. This distortion has to be determined by a comprehensive 3D investigation in a wind tunnel in order to obtain a distinct wind measurement [1].

Sonic anemometers are not limited to 3D units. More recent developments have now led to a wide selection of 2D (wind speed and wind direction) sonic units being available for applications that require "fit and forget" sensors.

Figure 2.3 Sonic Anemometer

2.2.5 Aerovane

An Aerovane combines a propeller and a tail on the same axis to obtain accurate and precise wind speed and direction measurements from the same instrument. In cases where the direction of the air motion is always the same, as in the ventilating shafts of mines and buildings for instance, wind vanes, known as air meters are employed, and give most satisfactory results [1].

Figure 2.4 Aerovane Anemometer

2.3 Hall-effect Sensor

Hall Effect sensor is a transducer that sense change in magnetic field. It is used in various sensors such as speed sensor, position sensor, and power sensor. When a magnet field from a source (permanent magnet or electromagnet) was pointed perpendicular to the sensor, the sensor will give an output. Depending on the type of Hall Effect sensor used, the output can be voltage or current, a pulse of high or low, or a continuous high or low. For speed sensing, the switch type of Hall Effect sensor will be used.

2.4 Speed Measurement Using Hall-Effect Sensor Switch Type

The most suitable method in measuring the speed of wind is using both propeller and a Hall Effect sensor. A small permanent magnet was attached on the propeller and when there are rotations on the propeller, it will cause a change in the magnetic field on the Hall Effect sensor. The output is produces each time the permanent magnet and the sensor are in perpendicular position to each other.

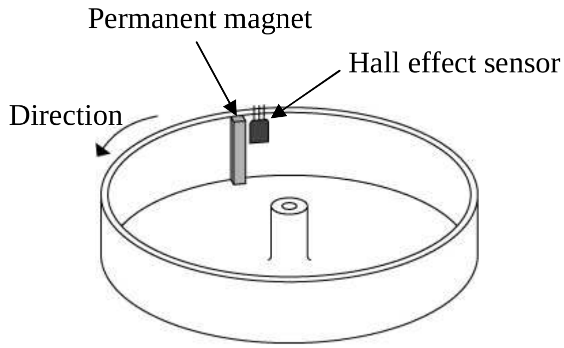


Figure 2.5 Hall Effect sensor attached on propeller with permanent magnet

The Hall Effect sensor is recommended by datasheet to be connected in circuit below [2].

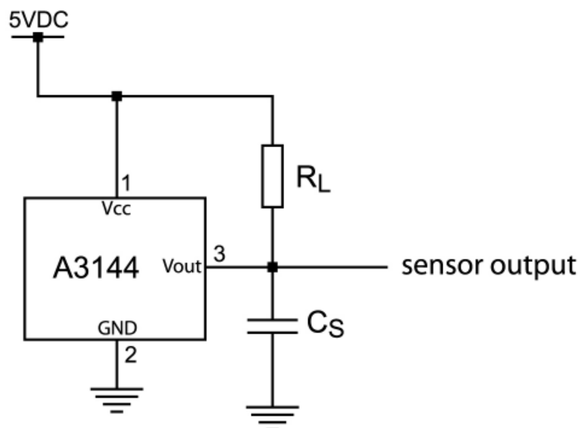


Figure 2.6 Recommended connection for Hall Effect sensor

Output of the Hall Effect sensor is 'HIGH' when there is no magnet is presented, and turns LOW when a magnet is perpendicular to the sensing surface of Hall Effect sensor.

2.5 Rotary Encoder

The most accurate way to measure or indicate positioning of something is by using encoder. For angular sensing, a rotary encoder can be used. The concept is; the given outputs indicate how much the sensing element was rotated. Generally, there are two types of rotary encoder. The first one is an incremental rotary encoder and the other one is an absolute rotary encoder. Each encoder can be found suitable depending on application and programming approach by the programmer. The rotary encoder is widely used in the industry for machinery, robotics, and for a simple example, in a computer mouse assembly. The construction of a rotary encoder consists of the rotary shaft and the circuit unit.

2.5.1 Absolute Rotary Encoder

An absolute rotary encoder produces unique binary code for each angle of rotation. The contacts inside the encoder move and each angle was set to different configuration. An example of a binary code, in a simplified encoder with only three contacts, is shown below [3];

Table 2.1 Standard binary encoder

Sector	Contact 1	Contact 2	Contact 3	Angle
1	off	off	off	0° to 45°
2	off	off	on	45° to 90°
3	off	on	off	90° to 135°
4	off	on	on	135° to 180°
5	on	off	off	180° to 225°
6	on	off	on	225° to 270°
7	on	on	off	270° to 315°
8	on	on	on	315° to 360°

**Off is '0', On is '1'*

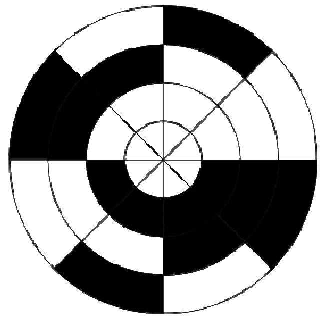


Figure 2.7 Rotary encoder for angle-measuring devices marked in 3-bit binary

The inner ring corresponds to Contact 1 in the Table 2.1. Black sectors are "on". Zero degrees are on the right-hand side, with angle increasing anti-clockwise.

In general, the relation between the number of contact and the distinct position is 2^n, where *n* is the number of contact. As for example above, the number of contacts is 3 which can lead the rotary encoder for 8 positions. However, this system has drawbacks - which are, if the system stops at two adjacent sectors or if the contact is not properly aligned.

To illustrate this problem, consider what happens when the shaft angle changes from 179.9° to 180.1° (from sector 4 to sector 5). At some instant, according to the above table, the contact pattern will change from off-on-on to on-off-off. However, this is not what happens in reality. In a practical device, the contacts are never perfectly aligned, and so each one will switch at a different moment. If contact 1 switches first, followed by contact 3 and then contact 2, for example, the actual sequence of codes will be;

Off-on-on (starting position)

On-on-on (first, contact 1 switches on)

On-on-off (next, contact 3 switches off)

On-off-off (finally, contact 2 switches off)

From Table 2.1, sectors corresponding to these codes, in order, they are 4, 8, 7 and then 5. So, from the sequence of codes produced, the shaft appears to have jumped from sector 4 to sector 8, and then gone backwards to sector 7, then backwards again to sector 5, which is where we expected to find it. In many situations, this behavior is undesirable and could cause the system to fail. For example, if the encoder were used in a robot arm, the controller would think that the arm was in the wrong position, and will try to correct the error by turning it through 180°, perhaps causing damage to the arm.

To avoid this problem, grey encoding is used. The system counts binary number by only one bit change at a time. Grey code counting would be as in Table 2.2.

Table 2.2 Gray coding

Sector	Contact 1	Contact 2	Contact 3	Angle
1	off	off	off	0° to 45°
2	off	off	on	45° to 90°
3	off	on	on	90° to 135°
4	off	on	off	135° to 180°
5	on	on	off	180° to 225°
6	on	on	on	225° to 270°
7	on	off	on	270° to 315°
8	on	off	off	315° to 360°

**Off is ‘0’, On is ‘1’*

The ring’s configurations on the disc have to be reconstructed.

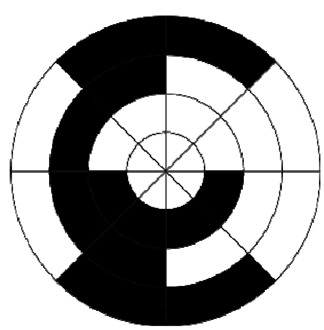


Figure 2.8 Rotary encoder for angle-measuring devices marked in 3-bit binary-reflected Gray code (BRGC)

The inner ring corresponds to Contact 1 in the Table 2.2. Black sectors are "on". Zero degrees are on the right-hand side, with angle increasing anticlockwise.

2.5.2 Incremental Rotary Encoder

An incremental rotary encoder (also called relative rotary encoders) has two outputs called quadrature outputs. They can be either mechanical or optical. In the optical type there are two gray coded tracks, while the mechanical type has two contacts that are actuated by cams on the rotating shaft. The mechanical types require debouncing and are typically used as digital potentiometers on equipment including consumer devices. Most modern home and car stereos use mechanical rotary encoders for volume. Due to the fact that the mechanical switches require debouncing, the mechanical types are limited in the rotational speeds they can handle. The incremental rotary encoder is the most widely used of all rotary encoders.

The optical type incremental rotary encoder is used when higher RPMs are encountered or a higher degree of precision is required.

Incremental rotary encoders are used to track motion and can be used to determine position and velocity. This can be either linear or rotary motion. Because the direction can be determined, very accurate measurements can be made. They employ two outputs called A & B which are called quadrature outputs as they are 90 degrees out of phase. The state diagram:

Table 2.3 Gray coding for clockwise rotation

Phase	A	B
1	0	0
2	0	1
3	1	1
4	1	0

Table 2.4 Gray coding for counter clockwise rotation

Phase	A	B
1	1	0
2	1	1
3	0	1
4	0	0

These signals are decoded to produce a count up pulse or a count down pulse. For decoding in software, the A & B outputs are read by software, either via an interrupt on any edge or polling, and the above table is used to decode the direction. For example if the last value was 00 and the current value is 01, the device has moved one half step in the clockwise direction. The mechanical types would be debounced first by requiring that the same (valid) value be read a certain number of times before recognizing a state change.

Rotary sensors that have a single output are not encoders and can not determine direction, but can sense RPM.

This same principle is used in old ball mouse to track whether mouse is moving to the right/left or forward/backwards [3].

2.6 Potentiometer

Potentiometer can be used to measure rotation and linear displacement, as it gives output in variable voltage when it is turn around. The variable voltage can be used to determine the direction or displacement when the potentiometer is properly attached to a moving object in modelling.

The normal potentiometer always has a dead band, the area not covered with contactor. The wind vane is free to move through 360 degrees, but there is a dead band of about 10 degrees at the crossover point in the potentiometer travel. As shown in the graph in figure 2.9, the output signal is zero volts for 5 degrees before the signal starts its linear rise, and the signal is at maximum voltage through 5 degrees at the other extreme of the travel. The dead band varies some from unit to unit. For the greatest possible accuracy, the exact dead band value must be determined [4].

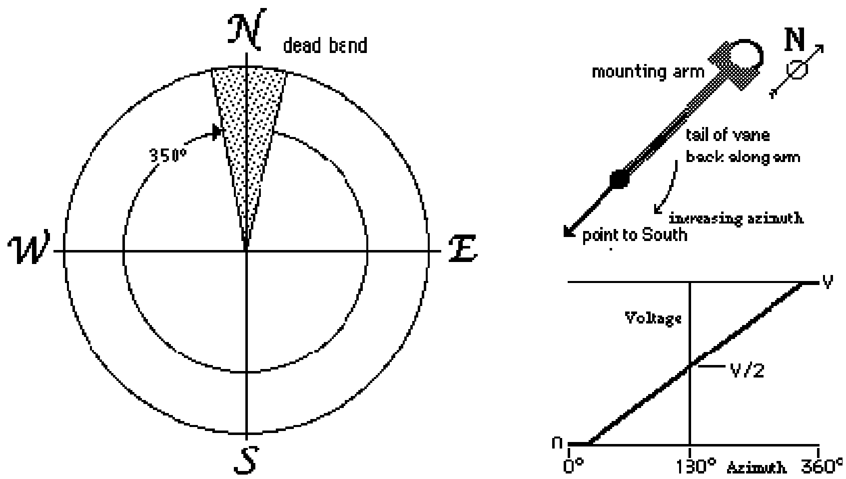


Figure 2.9 Potentiometer dead bands with output graph

2.7 Microcontroller

Microcontrollers must contain at least two primary components – random access memory (RAM), and an instruction set. RAM is a type of internal logic unit that stores information temporarily. RAM contents disappear when the power is turned off. While RAM is used to hold any kind of data, some RAM is specialized, referred to as registers. The instruction set is a list of all commands and their corresponding functions. During operation, the microcontroller will step through a program (the firmware). Each valid instruction set and the matching internal hardware are the features that differentiate one microcontroller from another [5].

Most microcontrollers also contain read-only memory (ROM), programmable read-only memory (PROM), or erasable programmable read-only memory

(EPROM). Al1 of these memories are permanent: they retain what is programmed into them even during loss of power. They are used to store the firmware that tells the microcontroller how to operate. Often these memories do not reside in the microcontroller; instead, they are contained in external ICs, and the instructions are fetched as the microcontroller runs. This enables quick and low-cost updates to the firmware by replacing the ROM.

The number of I/O pins per controllers varies greatly, plus each I/O pin can be programmed as an input or output (or even switch during the running of a program). The load (current draw) that each pin can drive is usually low. If the output is expected to be a heavy load, then it is essential to use a driver chip or transistor buffer.

Most microcontrollers contain circuitry to generate the system clock. This square wave is the heartbeat of the microcontroller and all operations are synchronized to it. Obviously, it controls the speed at which the microcontroller functions. All that is needed to complete the clock circuit would be the crystal or RC components. We can, therefore precisely select the operating speed critical to many applications.

To summarize, a microcontroller contains (in one chip) two or more of the following elements in order of importance [6]:

i. Instruction set
ii. RAM
iii. ROM, PROM or EPROM
iv. I/O ports
v. Clock generator
vi. Reset function
vii. Watchdog timer
viii. Serial port
ix. Interrupts
x. Timers
xi. Analog-to-digital converters

xii. Digital-to-analog converters

2.7.1 PIC 16F877A

PIC 16F877A is a microcontroller developed by Microchip Technology. It is developed using RISC technology and only consists of 35 instructions set. It can run on variable speed up to 20MHz. Beside that, the PIC draws low poser consumption and provides a high speed Flash/EEPROM technology. The operating voltage range is wide, as low as 2.0V up to 5.5V.

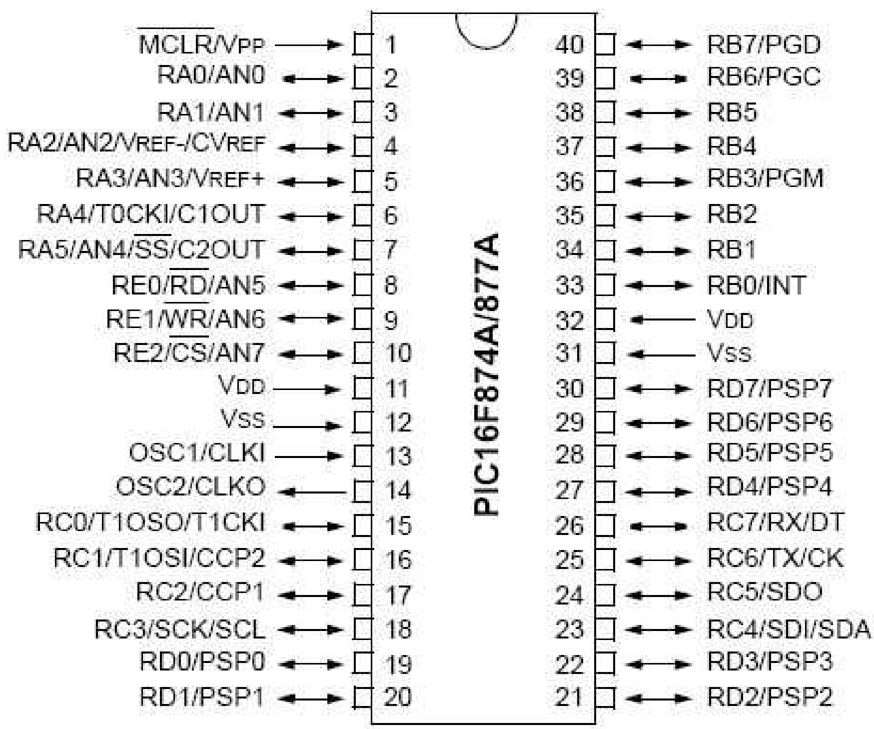


Figure 2.10 Physical look and diagram for PIC 16F877A

Features in PIC 16F877A;

1) Timer0: 8-bit timer/counter with 8-bit prescaler.
2) Timer1: 16-bit timer/counter with prescaler can be incremented during Sleep via external crystal/clock.

3) Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler.

4) Two Capture, Compare, PWM modules;

   - Capture is 16-bit, maximum resolution is 12.5 ns.

   - Compare is 16-bit, maximum resolution is 200 ns.

   - PWM maximum resolution is 10-bit.

5) Synchronous Serial Port (SSP) with SPI™ (Master mode) and I2C™ (Master/Slave).

6) Universal Synchronous Asynchronous Receiver.

7) Transmitter (USART/SCI) with 9-bit address detection.

8) Parallel Slave Port (PSP) – 8 bits wide with external RD, WR and CS controls (40/44-pin only).

9) Brown-out detection circuitry for Brown-out Reset (BOR).

For analog features, the PIC 16F877A have 10 bits, 8 channels analog-to-digital converter. With total of 5 I/O ports, the PIC16F877A is the most suitable device for controlling a lot of controlling circuits.

The summary of PIC 16F877A features and specification is shown in table below [7];

Table 2.5 PIC 16F877A features

Key Features	**PIC 16F877A**
Operating Frequency	DC – 20MHz
Reset (and delays)	POR, BOR (PWRT, OST)
Flash Program Memory(14-bit words)	8K
Data Memory (bytes)	368
EEPROM Data Memory (bytes)	256
Interrupts	15
I/O Ports	Ports A, B, C, D, E
Timers	3
Capture/Compare/PWM modules	2

Serial Communications	MSSP, USART
Parallel Communications	PSP
10-bit Analog-to-Digital Module	8 input Channels
Analog Comparators	2
Instruction Set	35 instructions
Packages	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN

2.8 16 x 2 Characters LCD

There are many types of LCD. 16 x 2 characters LCD is a LCD that display up to 16 characters per line and have 2 lines display. The input can be 4 or 8 bit binary and have 3 controls bit; 1) enable bit, 2) read/write bit, and 3) control bit. Voltage range for this LCD is between 4.5V to 5.5V. Backlight is implemented in this LCD.

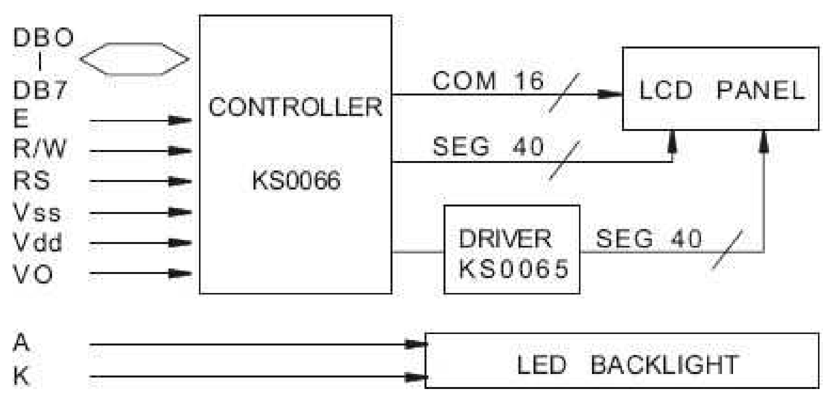


Figure 2.11 LCD block diagram

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this project, a microcontroller will be used as the central processing unit for digital wind speed and direction meter. The block diagram of the system is shown in Figure 3.1.

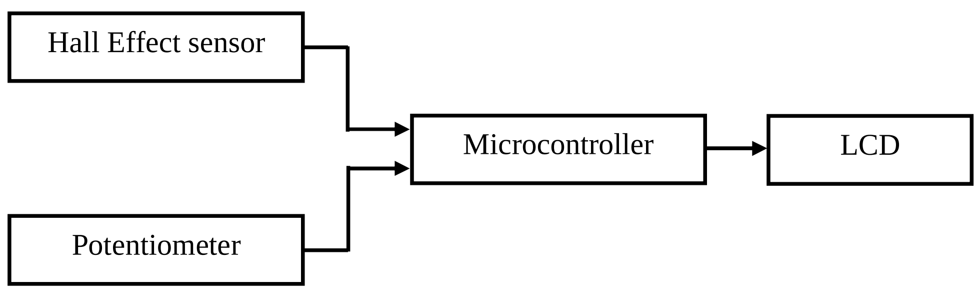


Figure 3.1 Block diagram of digital wind speed meter with wind direction system

The Hall Effect sensor will sense the rotation of propeller. The frequency of the rotation is measured by the microcontroller. Meanwhile, the potentiometer gives a variable analog input into the microcontroller for direction measurement. In the microcontroller, both input from Hall Effect sensor and potentiometer is processed and the input is displayed on LCD.

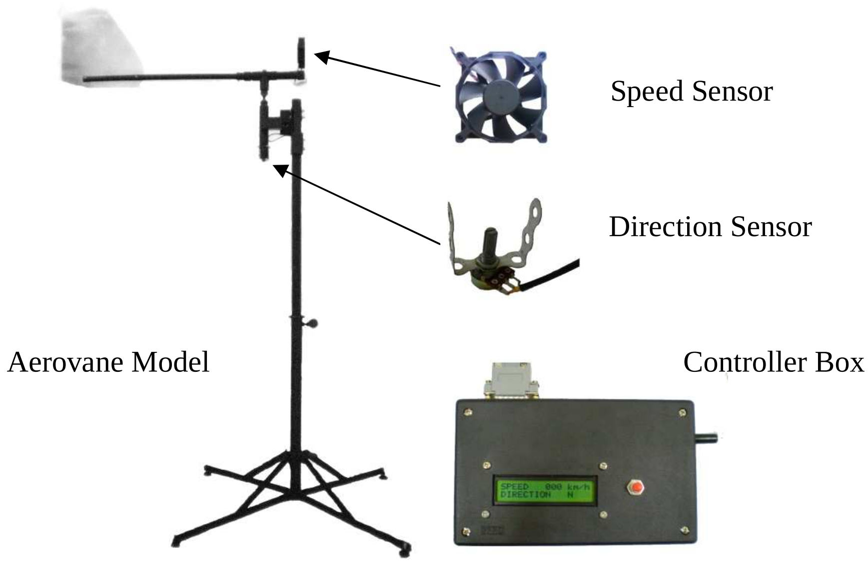


Figure 3.2 Picture of the overall project

Figure 3.2 shows the picture of the project. The project is divided into two parts: the software and hardware implementation. Each part of the project will be discussed in the following section.

3.2 Hardware Implementation

This section will discuss about the components that are used, including Hall Effect sensor, potentiometer, power supply 5V, microcontroller PIC 16F877A, and 16 x 2 characters LCD.

3.2.1 Hall Effect Sensor

Figure 3.3 illustrate the Hall Effect sensor used in this project.

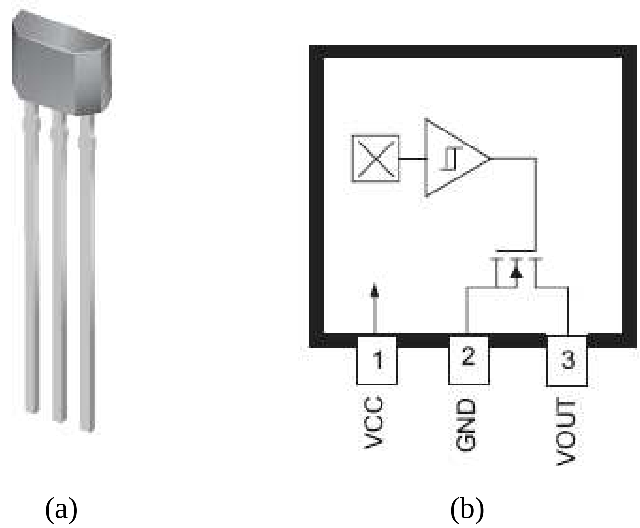


Figure 3.3 Hall Effect sensor; (a) Physical picture, (b) Internal circuit

The Hall Effect sensor used in this project is the A1104 chip manufactured by Allegro Microsystems, Inc. It is a unipolar continuous-time switch family. The sensor output turns on (switch low) when a south polarity magnetic field perpendicular to the Hall sensor exceeds the operating point threshold, B_{OP}. The output is capable of sinking up to 25mA and the output voltage is $V_{OUT(SAT)}$. When the magnetic field is reduced below the release point, B_{RP}, the sensor output goes high (turns off). The range between the B_{OP} and B_{RP} is called hysteresis, B_{hys}. The built-in hysteresis allows clean switching of the output, even in the presence of external mechanical vibration and electrical noise. Figure 3.4 shows the relationship between the parameters [2].

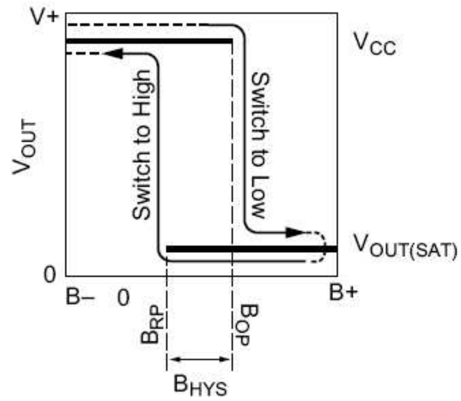


Figure 3.4 Switching behavior of Hall Effect sensor

According to the datasheet, powering-on the sensor in the hysteresis region, less than B_{OP} and higher than B_{RP} allows an indeterminate output state. The correct state is attained after the first excursion beyond B_{OP} or B_{RP}. The 'B' is the magnetic flux density which refers to the fix magnet attached on the propeller of speed sensor.

The A3314 Hall-effect sensor includes the following on a single silicon chip: voltage regulator, Hall-voltage generator, small-signal amplifier, Schmitt trigger, and NMOS output transistor. The integrated voltage regulator permits operation from 3.8 V to 24 V. Figure 3.5 shows the basic connection for Hall Effect sensor [2].

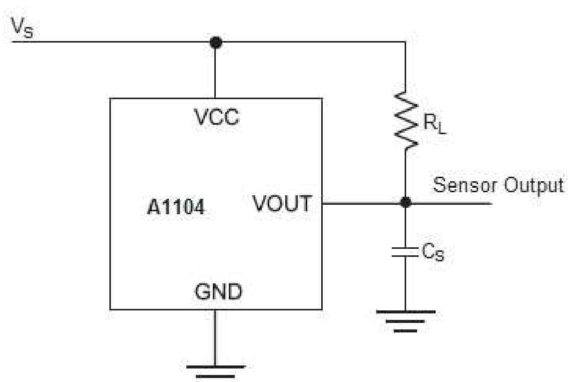


Figure 3.5 Basic connection of Hall Effect sensor

3.2.2 Potentiometer

Potentiometer is used for direction sensor. The resistance value of the potentiometer is 10kΩ. The function of the potentiometer is to give analog output with respect to the direction of the wind. The handle of the potentiometer is attached on the aerovane shaft. When the wind blow and the tail of aerovane follow the wind direction, so do the potentiometer handle. The analog output from the potentiometer is proportional to the direction of the wind.

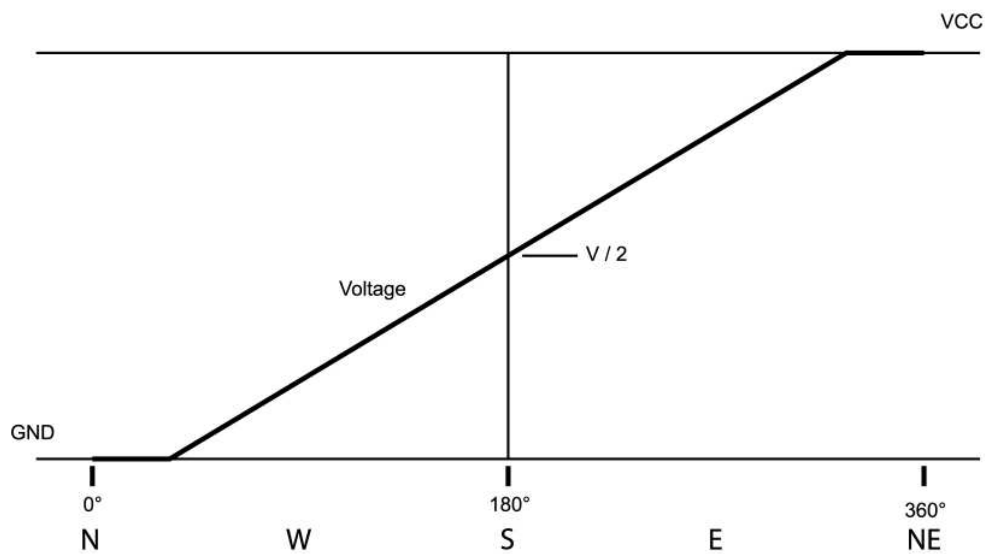


Figure 3.6 Analog outputs from potentiometer

From the graph on the figure above, we can see the constant state in the beginning and the end of potentiometer movement. It is caused by a dead band in the potentiometer which reduces the angle reading to 70°. Because of the dead band, the measured direction is not suitable to be displayed in degree. The solution for this problem is by displaying the direction on an absolute direction.

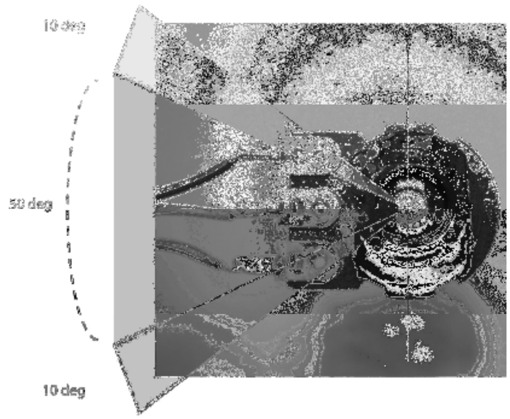


Figure 3.7 Dead bands on potentiometer

The 50° is the dead band which has no voltage in this angle. Both the 10° angles are the constant value of potentiometer. If the potentiometer's contact moves to this position, the output will be a constant value whether Vcc or 0V (GND). All the 8 absolute directions are determined as follows;

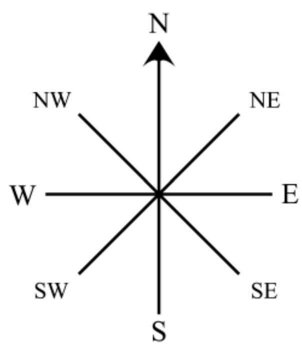


Figure 3.8 Absolute directions for output from potentiometer

3.2.3 5V Power Supply

The entire component used in this project needs a constant dc voltage average of 5V. To meet these requirements, a dc regulator, IC LM7805 is used. The IC is built to regulate dc input and provide a constant dc output of 5Vdc.

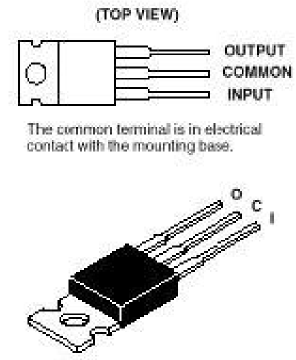


Figure 3.9 IC 7805 physical view

To reduce the noise, capacitors can be placed in parallel to output.

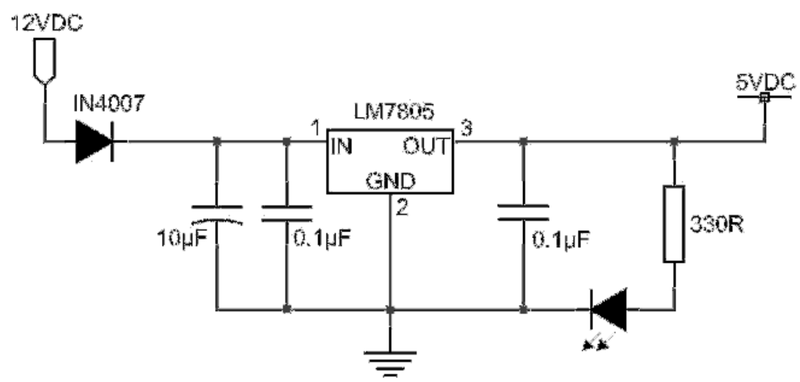


Figure 3.10 Schematic circuits 5V power supply

3.2.4 PIC 16F877A Microcontroller

The PIC16F877A works as a central controller for this project. It is manufactured by Microchip Technology Inc. It has 5 ports which is the most important specification to be implemented in this project. The PIC 16F877A features used in this project are as follows;

1. Analog to digital module
2. Timer interrupt
3. External interrupt

4. High level programming language

The circuit configuration for digital wind speed meter and direction is shown in the figure below.

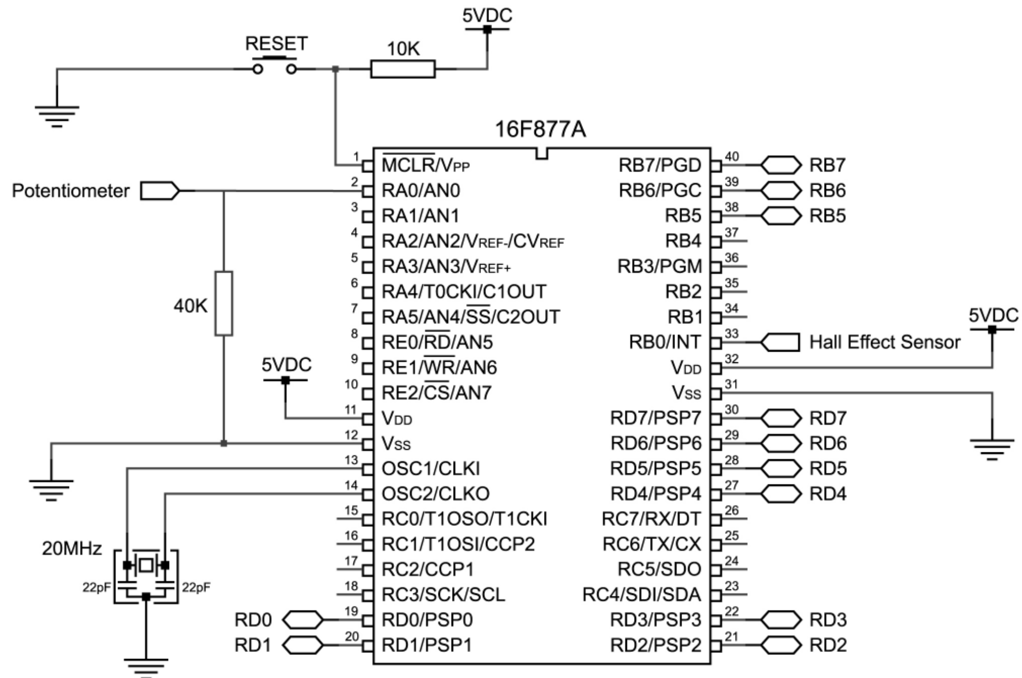


Figure 3.11 Schematic circuits for PIC16F877A

Table 3.1 shows the pin configuration for digital wind speed meter with wind direction system. A 40kΩ resistor is connected from ground to RA0 for setting the pin in a 'low' state by default. The resistor value must be higher than the value of potentiometer used. The main reason for placing the resistor is to prevent the pin RA0 from being floated when the potentiometer contactor goes to non-contacting area (dead band), since the ADC (analog-to-digital) output will become random if the pin is floating. Analog signal received on pin RA0 varies between V_{DD} (5V) and V_{SS} (0V). The ADC result is in 8-bit binary value which means 0-255 in decimal value. The PIC16F877A will receive pulses on the RB0/INT pin and an external interrupt occurs on falling edge of the pulses.

Table 3.1 Pin connection of PIC16F877A for digital wind speed meter with direction circuit.

Pin no.	Pin name	Discription	Application
11,32	V_{DD}	Positive supply(+5V)	Power supply to PIC
12,31	V_{SS}	Ground reference	Ground reference
13	OSC1	For oscillator or resonator	Using 20MHz crystal with 22pF capacitor
14	OSC2		
1	$\overline{\text{MCLR}}$	Reset input	Always set to high
2	RA0/AN0	Analog input channel 0	Input for direction sensor
33	RB0/INT	External interrupt input	Input from hall effect sensor
19,20,21,22, 27,28,29,30	RD(0-7)	Input/output port	Data line for LCD
38,39,40	RB(5-7)	Input/output port	Control bit for LCD

The PIC16F877A can be operated in 4 different oscillator modes. This includes LP (low-power crystal), XT (crystal/resonator), HS (high-speed crystal/resonator), and RC (resonator/capacitor). HS mode has been chosen for this project. The PIC16F877A will have an external clock source to drive the OSC1/CLK1 pin. The crystal used is 20MHz.

3.2.4.1 External Interrupt in PIC16F877A

PIC16F877A can have external interrupt on port B. For speed measurement, the sensor output is connected to the pin RB0/INT. The interrupt module must be initilize in OPTION_REG and INCON register through PIC program.

3.2.5 16x2 Character LCD

For displaying the output, the 16x2 character LCD is used. The LCD 16 characters per line and has 2 lines display. It supports 4-bit and 8-bit data input.

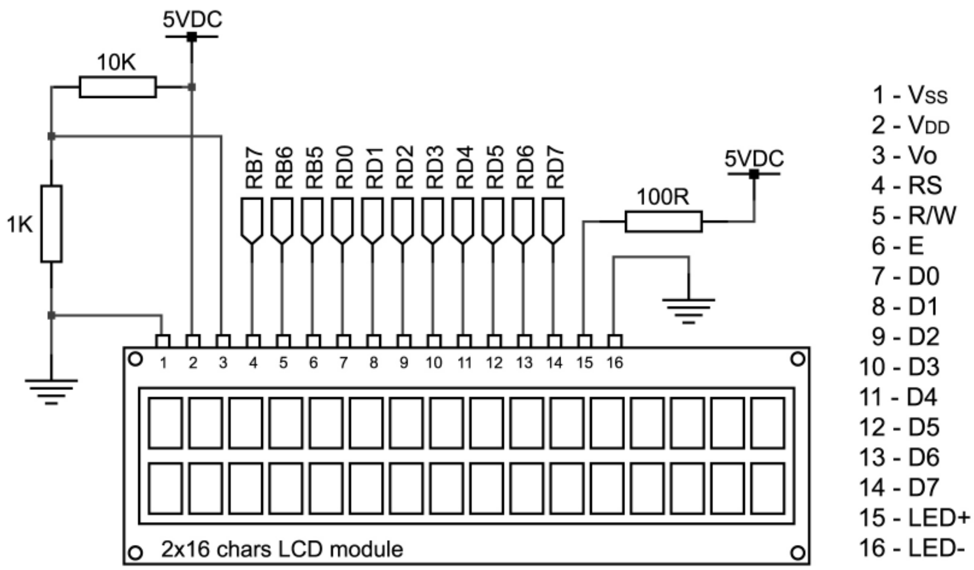


Figure 3.12 LCD circuit

8-bit data inputs are used in this project. Data is transmitted using port D. The control bit is on port B 5, 6, and 7. RS pin is used for register selection while R/W is for reading or writing the data on the LCD. The E pin is used to enable the LCD. LCD is enabled when the pin is in 'low' state. The LCD comes with backlight which can be turned on by supplying the voltage on pin 15 and 16. A switch is used to switch on the backlight.

3.3 Software Implementation

For software implementation, MicroCode Studio software is used to program the PIC in BASIC language. The BASIC language is easier to understand compared to assembly language programming.

3.3.1 Wind Speed Meter with Wind Direction Algorithm.

The microcontroller (PIC16F877A) functions as a central processing unit for all the input and output in this project. It receives pulses from speed sensor and analog input from potentiometer (direction sensor). The pulses are count in 1 second interval and the analog input is converted to 8-bit digital stream. Both input are processed and the output is displayed on LCD.

A working algorithm for wind speed meter with direction system has to be developed for programming the microcontroller. The algorithm is represented in flow chart in figure 3.13. There are two main parts of the program, the main program and the interrupt program. The main program runs in a looping state until the interrupt happen. There are two interrupts used in this project; timer0 overflow interrupt and external interrupt. Whenever interrupts happen, the program will immedietly switch to interrupt routine.

The MicroCode Studio can compile the BASIC language to assembly language and hex file. The hex file then used to be load into the PIC16F877A using PIC programmer. The programmer used in this project is Melabs programmer USB type from microEngineering Labs, Inc.

The overall programming codes are attached in appendix A.

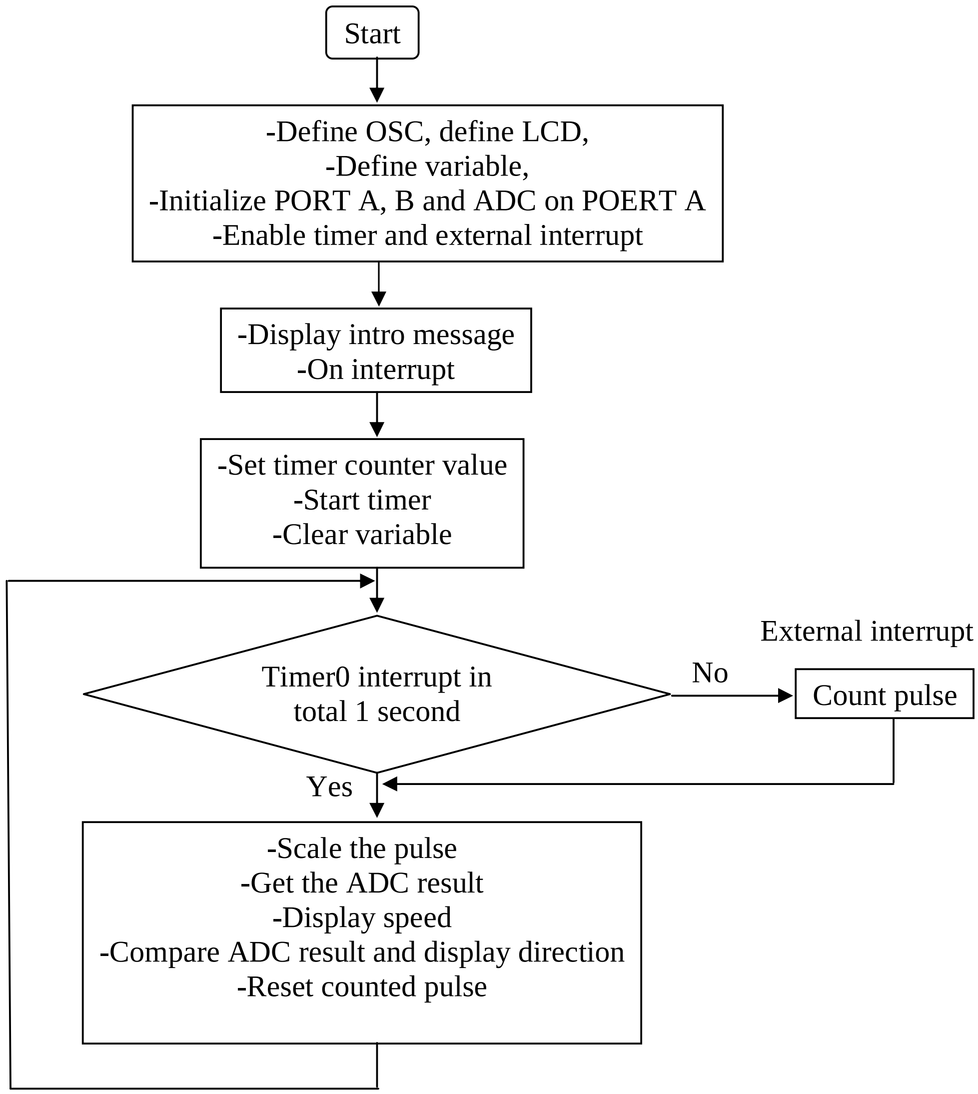


Figure 3.13 Main program flow chart

3.3.1.1 Explanation on Main Program

There are 4 key parts in the main program;

a) Define oscillator, LCD data and control bit, and variables.

The first element of the program is defining. The first part to be defined is the oscillator frequency used for PIC. The 20MHz crystal is used in the hardware and the default setting in the MicroCode Studio is 4MHz. The oscillator must be defined to make sure that the program timing runs according to the real time. This is important, for example in the PAUSE command. The PAUSE command is followed by a value in micro seconds. The microsecond is counted automatically by MicroCode Studio from the defined oscillator. If no oscillator is defined on top of the program, it will use the default value of 4MHz.

To setup the LCD, the data and control bits must be defined first. The list of must-define variables are as follows;

i. LCD data port
ii. LCD bus size
iii. LCD register select port and bit
iv. LCD enable port and bit
v. LCD read/write port and bit

The data port is set to port D, using 8-bit bus size. The LCD register select is port B, bit 7. The LCD enable bit is on port B, bit 5 and the LCD read/write bit is on port B, bit 6.

Variables to be used in the program must be defined first before it can be used. This involves defining the name of the variables and the size of the variables. Since the PIC16F877A only supported up to 16-bit, the maximum size that can be used is a word. To define a name to certain constant, the command CON is used. For this project, the SCALE variable is defined to certain constant. The SCALE value is determined by calibration precesses.

b) Configure registers.

A few registers in the microcontroller are used in this project and these registers must be configured before the ports or modules in the microcontroller can be used. A TRIS register controls the flow on a port, whether it is input or output. Setting the TRIS bit to ‘1’ makes the corresponding port pin an input and setting the TRIS bit ‘0’ makes the corresponding port pin an output. [8]

The value of prescaller used in timer0 is set in OPTION_REG register.

OPTION_REG REGISTER (ADDRESS 81h, 181h)

R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
$\overline{RBPU}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0
bit 7							bit 0

Figure 3.14 OPTION_REG register

The value 2 in decimal number loaded onto the OPTION_REG register will set %00000010 in binary number. The prescaller assignment is set by the last three bits as table below;

Table 3.2 Prescaller rate select bit

Bit value	TMR0 rate
000	1 : 2
001	1 : 4
010	1 : 8
011	1 : 16
100	1 : 32
101	1 : 64
110	1 : 128
111	1 : 256

The value selected for the prescaller is 8. The prescaller is the value to scale the basic timing instruction. For 20MHz, the basic timing instruction is $\frac{1}{\frac{20MHz}{4}}$ = 0.2 microsecond. By using the prescaller of 8, the timer clock rate will be 1.6 microsecond.

INTCON is a register for enabling global interrupt, timer0 overflow interrupt, pin RB0/INT interrupt and port B interrupt. For this project, the global interrupt, timer0 and RBO/INT pin interrupt should be enabled by setting '1' to specific bit in INTCON register. The value $A0 loaded to this register will enable the GIE and TMR0E bit. GIE bit is for global interrupt enable bit and TMR0E is for timer0 overflow interrupt enable bit.

INTCON REGISTER (ADDRESS 0Bh, 8Bh, 10Bh, 18Bh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-x
GIE	PEIE	TMR0IE	INTE	RBIE	TMR0IF	INTF	RBIF
bit 7							bit 0

Figure 3.15 INTCON register

The analog-to-digital module has 4 registers; A/D result high register (ADRESH), A/D result low register (ADRESL), A/D control register 0 (ADCON0), and A/D control register 1 (ADCON1). The ADCON0 controls the operation of the analog-to-digital module, while the ADCON1 configure the function of port pins. The port pins can be configured as analog input or digital input/output.

ADCON0 REGISTER (ADDRESS 1Fh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0
ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/$\overline{DONE}$	—	ADON
bit 7							bit 0

Figure 3.16 ADCON0 register

ADCON1 REGISTER (ADDRESS 9Fh)

R/W-0	R/W-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
ADFM	ADCS2	—	—	PCFG3	PCFG2	PCFG1	PCFG0
bit 7							bit 0

Figure 3.17 ADCON1 register

The ADCON0 and ADCON1 are loaded with %11000001 and %00000000. For ADCON0, the first 2 bits are for ADC conversion clock. The value of 11 implies the clock used for ADC is derived from the internal analog to digital RC oscillator. The next 3 bits are the channel select for input. 000 means channel 0 (RA0). $GO/\overline{DONE}$ is the status bit for ADC and it is cleared in this step. The last bit is the ADON bit which is used to enable ADC module.

ADCON1 sets the function of ADC. When loaded with %00000000, the ADFM bit will determine the result form in left justified. The last 4 bits are used to set the input port as digital input or analog input and the reference voltage. For 0000, the input set to all analog and the voltage reference for V_{REF+} is V_{DD} and the V_{REF-} is V_{SS}.

c) Intro program.

The intro program is mainly about introduction show about the project, clearing variables before it will be used and on the interrupt services at the end of the intro program. At first, the program will hold for 1 second for LCD to be initialized. Then, a set of intro messages will appear on LCD.

The timer0 will start after the intro messages end. Before that, the timer will be loaded with the counter value. The counter value is the count time of the timer before it will overflow and generate interrupt. It is an 8-bit counter and it counted from 255 to 0. To count 125 times, the counter value that should be loaded is 256 – 125 = 131. This value is then loaded to TMR0 registers. Timer0 overflow interrupt will occur every 1.6 microsecond x 125 = 0.2 millisecond [9].

After all variables are cleared, the interrupt service was turn on.

d) Looping program.

The looping program is labeled with “LOOP” and the program will execute in normal conditions (if no interrupts occurs). In this program, the output on LCD is executed. The first step in looping program is scanning the UPDATE variable. The program will only continue if the UPDATE value is 1. Otherwise, it will loop back until the value is 1. The UPDATE variable will be 1 from the interrupt routine. It will determine whether the 1 minute counting is finished or not.

When the UPDATE value is 1, the program loop continues. The next step is setting the UPDATE value back to 0. Then, the counted pulse per minute is the scale for output in metric value. Analog to digital output value is stored in ANGLE variable.

Next, displaying output value to the LCD started with clearing the LCD. The speed value in km/h is displayed in the first line of the LCD. The direction of the wind is determined by comparing the analog-to-digital output with 8 specific directions.

Table 3.3 ADC output to absolute direction conversion

Specific direction	ADC output
N	0
NE	1 - 9
E	10 - 56
SE	57 - 104
S	105 - 151
SW	152 - 199
W	200 - 246
NW	247 - 255

While the ADC is using 8-bit conversion, the decimal value for ANGLE variable varies from 0 to 255.

At the end of the LOOP program, the variable of counted pulse in variable PULSE is cleared and the program loops back to the top LOOP program.

3.3.1.2 Explanation on Interrupt routine

Interrupt is enabled using BASIC is using ON INTERRUPT command. It will activate the internal interrupt handling and quickly jump to interrupt handler as soon as possible after receiving interrupt. The DISABLE command is placed before the interrupt routine. It will disable all interrupt services when the interrupt routine is executed.

On the same interrupt handler, both external and timer0 overflow interrupt input is processed.

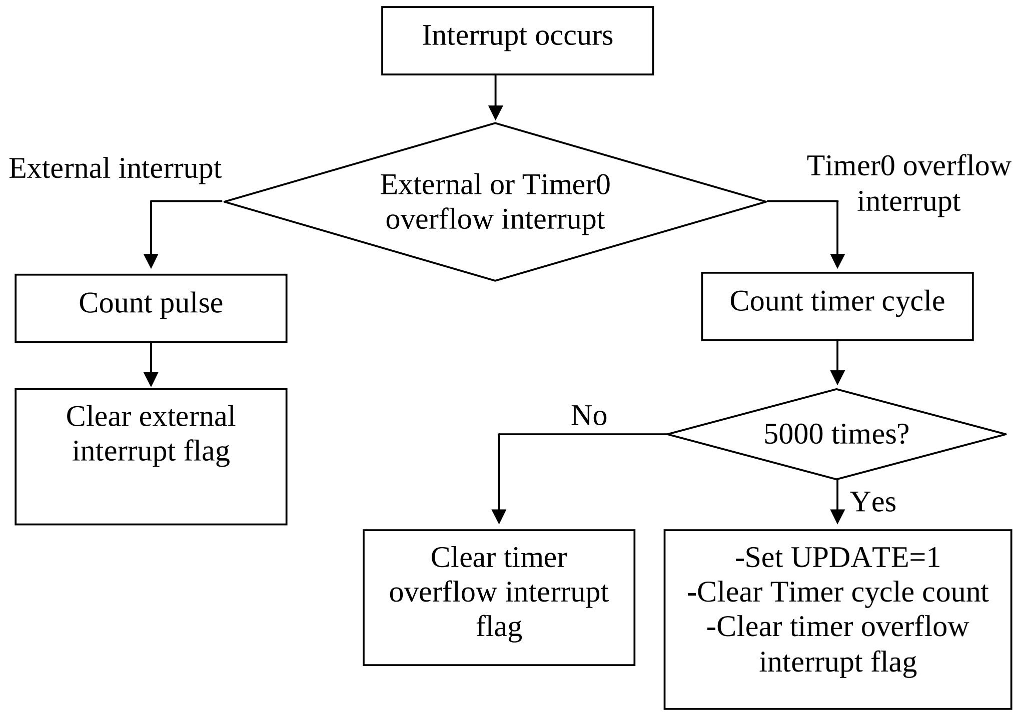


Figure 3.18 Interrupt handler flow chart

In this project, interrupt occurs in two ways. One is when the transition from high to low is detected on port B pin 0 and another way is from timer0 overflow interrupt. The INTCON register in PIC 16F877A contains flags for both interrupt. When interrupt occurs, respective bit for each interrupt will set.

Once external interrupt received, the interrupt handler will count up the variable PULSE. Then, the external interrupt flag in INTCON will be clear to reenable the external interrupt.

After the timer0 interrupt is enabled, it will generate timer interrupt every specific time interval. From calculated value of timer0 overflow before, timer0 overflow interrupt occurs every 0.2 millisecond. The handler will count the interrupt occurs. The counted timer0 interrupt occurs need to be equal to 5000 to get the 1 second in total time. If the counted timer0 interrupt occurs less than 5000, the program will clear the timer overflow interrupt flag to reenable the timer0 interrupt.

After 5000 timer0 interrupt occurs, program will set the UPDATE variable to 1 and clear the counted timer0 interrupt occurs.

After all interrupts happened, RESUME command used to reenable the interrupt services and return to where the main program was before the interrupt occurred.

3.4 Aerovane Modelling

Aerovane model can be divided into 2 parts. The first part is for speed measurement, propeller. The main body is for another part, where wind direction can be measured from the moving body which follows the wind direction.

3.4.1 Speed Sensor

The speed sensor is placed on the front of the model. It is where the wind will come from and there should be no obstacle that will block the wind source. For this project, a 7.5cm diameter brushless DC fan was used for the basic component for the speed sensor. The wire winding and the permanent magnet is removed from the place. A small piece of permanent magnet is attached on the previous permanent magnet placing and the Hall Effect sensor is placed perpendicular to the permanent magnet.

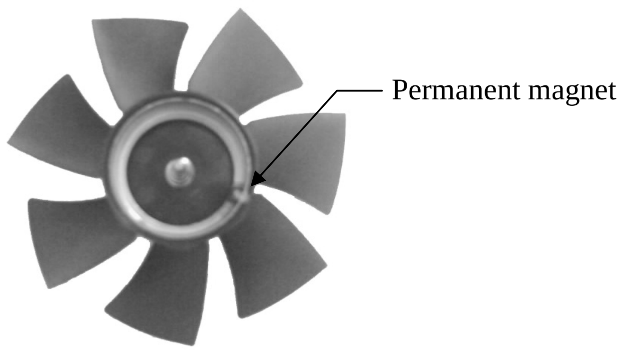


Figure 3.19 Permanent magnet attached on the propeller

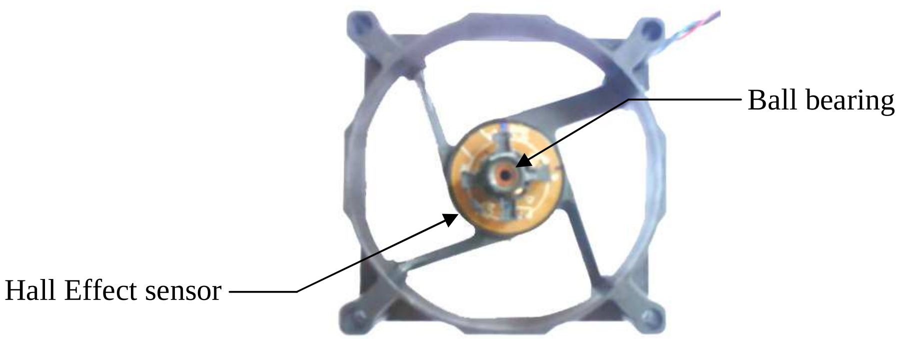


Figure 3.20 Hall Effect sensors on fan housing

The center of the fan housing is equiped with ball bearing. The bearing will reduce the friction between the propeller and the housing. The less the friction, the more sensitive propeller will be.

Figure 3.21 Complete set of wind speed sensor

Speed sensor must move together with the body of windvane. This will make the wiring diffulties for speed sensor. The wire cannot be connected directly as it will cause the wire twisted and stop the body from moving around. It also might break the wire. Because of that, three contactors were used to solve the problem. The three contactors used to connect power supply, ground and output line for speed sensor.

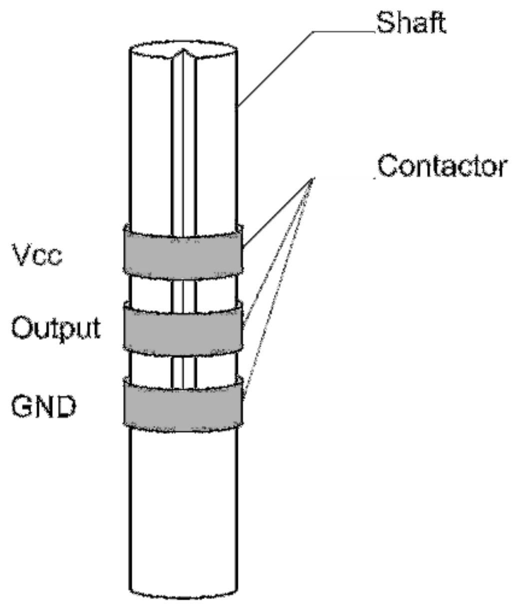


Figure 3.22 Moving shaft and contactor

3.4.2 Direction sensor

For direction sensor, potentiometer is placed at the bottom of the main shaft. While the shaft is spin by the wind direction, the potentiometer used to determine the direction of the wind.

The potentiometer is attached at the bottom of the shaft using shaft connector. The shaft connector is made from wire rubber tube.

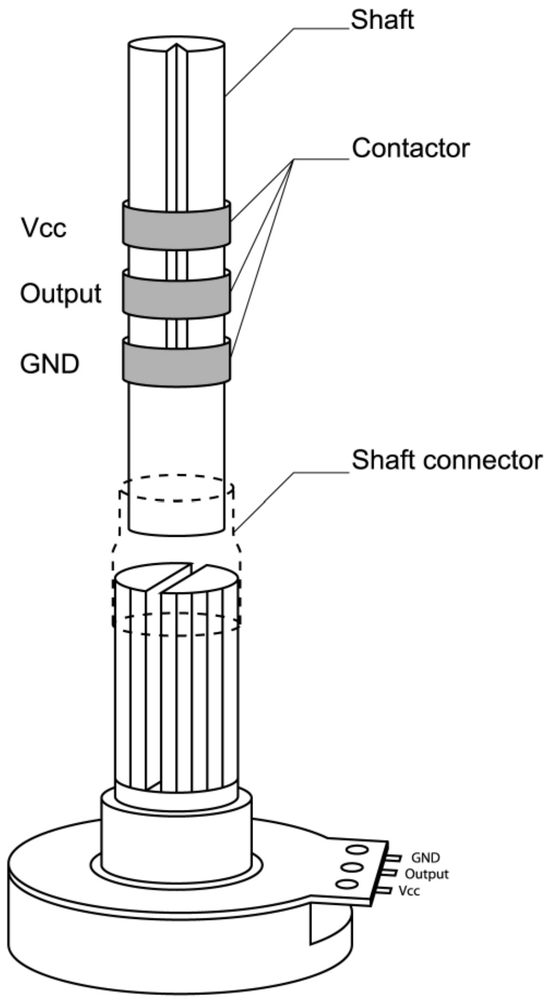


Figure 3.23 Potentiometer connected to the shaft

3.4.3 Aerovane Model

The aerovane modelling based on the pictures of comersial aerovane taken from the internet. For this project, the parts for building the aerovane were made from the local available materials.

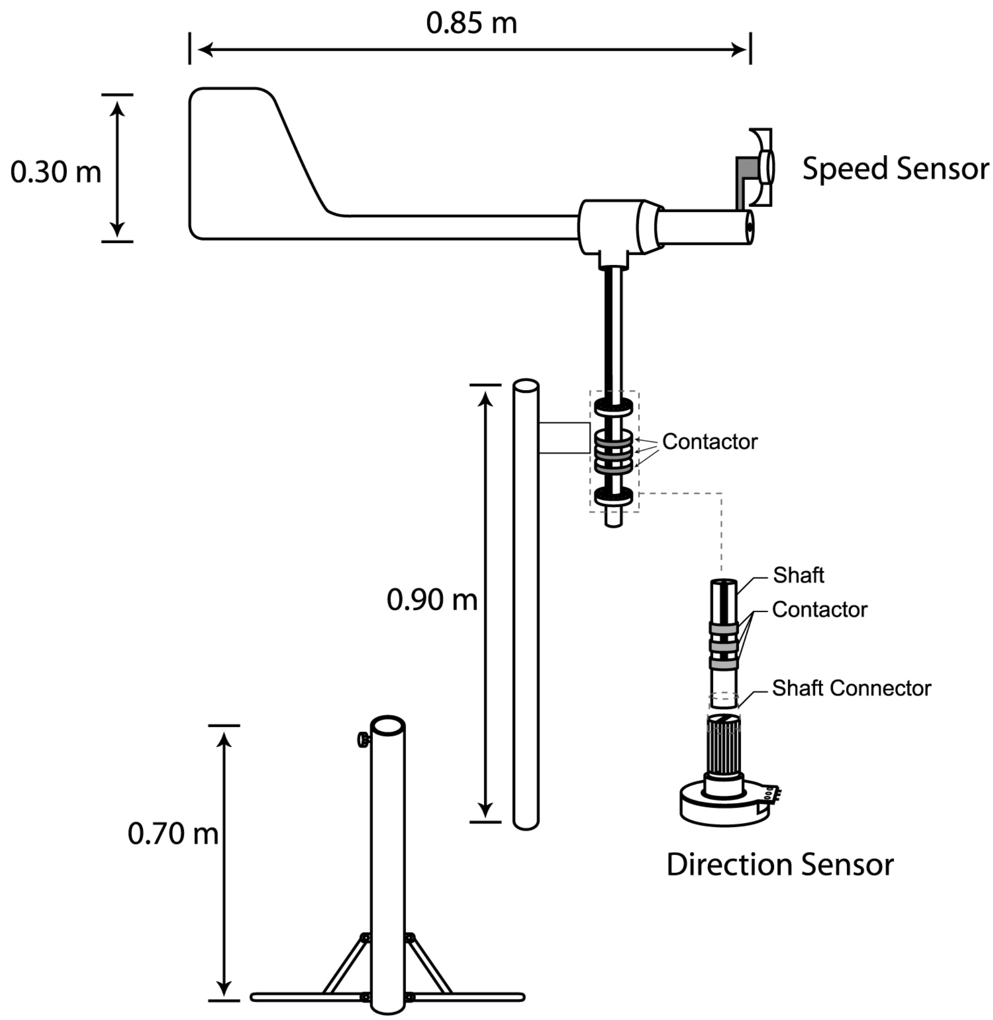


Figure 3.24 Aerovane modelling

The main body was constructed using PVC pipe connector. For the stand, the local umbrella stand was used. The tail was made by PVC pipe and alluminium plate.

3.5 Calibration Process

Sensor used for speed measurement will provide output in pulses. A pulse is generated every rotation of propeller. The pulse then counted in PIC 16F877A microcontroller in 1 second interval. From here, the pulse per second is obtained. However, this value means nothing to the real world. The value should be calibrated to be display in metric unit. For this project, the km/h unit was choosen. To get the equivalent value for the pulses in km/h, calibration process is needed.

The calibration process is the process to configure a device or sensor with respect to the standard value. The most simple calibration method is simply comparing both outputs, from the standard device with the uncalibrated device. The same way applied to this project. The output from the sensors in pulse per second is compared to other devices, measuring the same wind flow.

For this project, two comparing methods used to be calibrated with the sensor. The first method is using a car running on a constant speed in no-wind road and the sensor is attached on the outside of the car. The sensor must be placed on acceptable distance to make sure the sensor is not affected to the car aerodynamic effects. Suitable road must be considered before doing the calibration. Two roads and the wind flow pattern on the area of the road on specific time have been identified.

The first road is on the residential area located on Jalan BGP1, 26300, Gambang, Kuantan. The road is straight; however the distance is not suitable for high speed calibration. The maximum speed reading for this road is only 40km/h. Reading is taken for every 10, 20, 30 and 40km/h. The set of reading is taken 2 times.

Table 3.4 Table used for wind speed sensor calibration

Speed (km/h)	Pulse/second
10	
20	
30	
40	

The result will be discussed on the next chapter.

Another road is on the MEC highway. The highway is long enough to make a high speed calibration however, it is an open area. More wind will flow there and it more noise to the reading will be obtained. The time of less wind flow should be considered. The same table and constants speed from previous road is used. 3 readings have been taken. The highspeed calibration on 60, 80, and 90 km/h test were done once. Care should be taken for the sensor as it is not tested to endure the highspeed force.

The second comparison calibration is using the actual anemometer. The anemomter used is mobile type anemometer. It is small in size and light weight. Powered with 3volt cell, the output is display in km/h. The calibration technique used is attaching the anemometer side by side with the wind speed sensor. Then, both sensors are pointed to fan and both readings are taken.

Figure 3.25 Calibration methods 1

Figure 3.26 Calibration methods 2

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

This project has been successful in achieving all scope. The speed value in km/h and the direction in 8 specific directions can be displayed on LCD. However, the speed sensor need to be calibrated before in can be scale to km/h unit. The direction determintain process has been explained in previous chapter.

To calibrate the wind speed sensor, calibration processes have been conducted. The calibration is done in several methods explained in previous chapter. This calibration is conducted to get the scalling factor for the wind speed sensor.

4.2 Calibration Method 1

The first calibration method is by using a car as discussed in the previous chapter. For calibration using a car, the results are shown below;

Table 4.1 Result for calibration conducted on 2:30 a.m, 28/10/2007

Speed(km/h)	Pulse/s
10	28
20	45
30	63
40	83

Table 4.2 Result for calibration conducted on 3:00 a.m, 28/10/2007

Speed(km/h)	Pulse/s
10	26
20	42
30	59
40	82

Table 4.3 Result for calibration conducted on 11:00 a.m, 31/10/2007

Speed(km/h)	Pulse/s
10	24
20	33
30	59
40	80

Table 4.4 Result for calibration conducted on 12:00 p.m, 31/10/2007

Speed(km/h)	Pulse/s
10	26
20	34
30	59
40	77

Table 4.5 Result for calibration conducted on 2:15 p.m, 31/10/2007

Speed(km/h)	Pulse/s
10	22
20	35
30	57
40	78

Table 4.6 Result for high speed calibration conducted continues from previous table

Speed(km/h)	Pulse/s
60	132
80	170
90	195

There are 6 sets of readings in total. The graph for each set shown below;

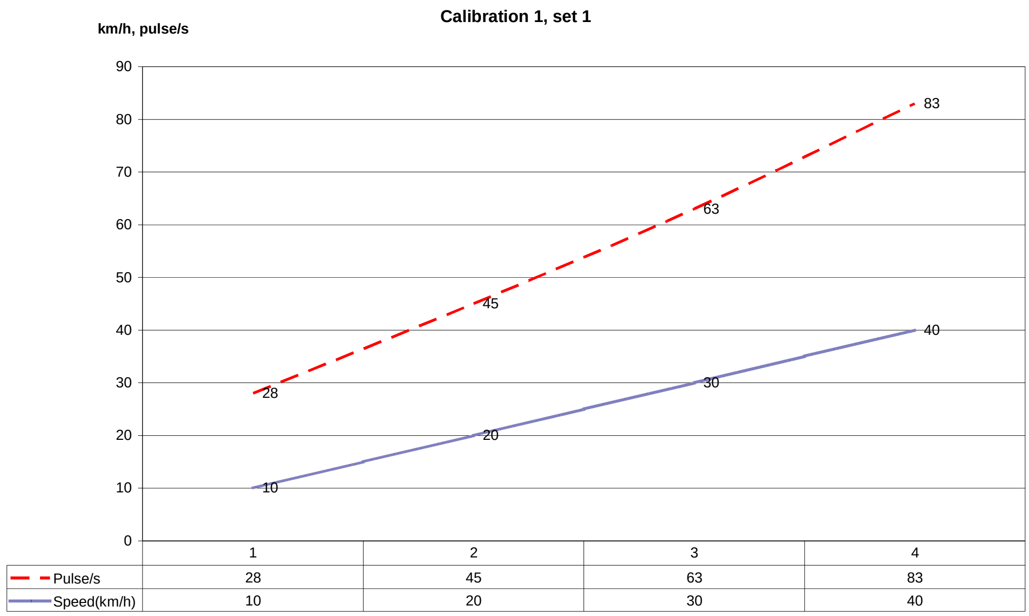
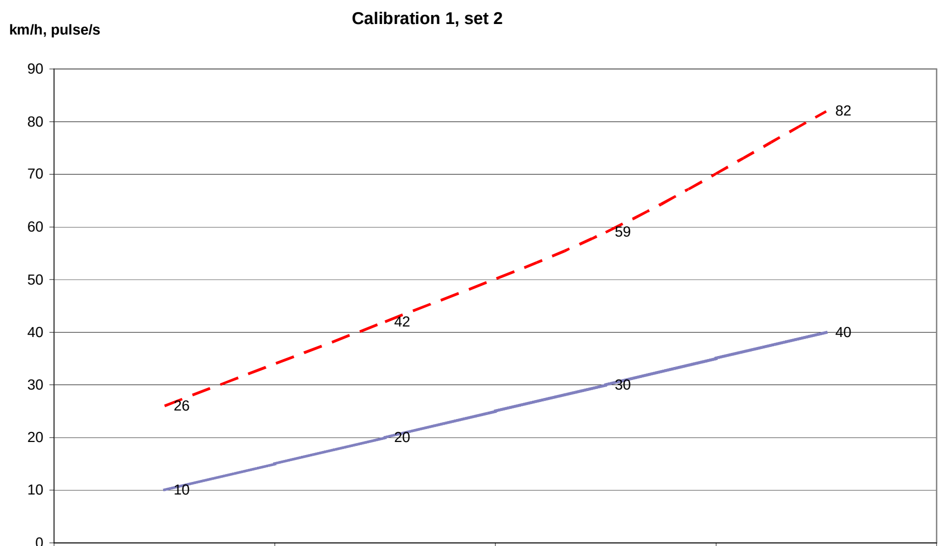
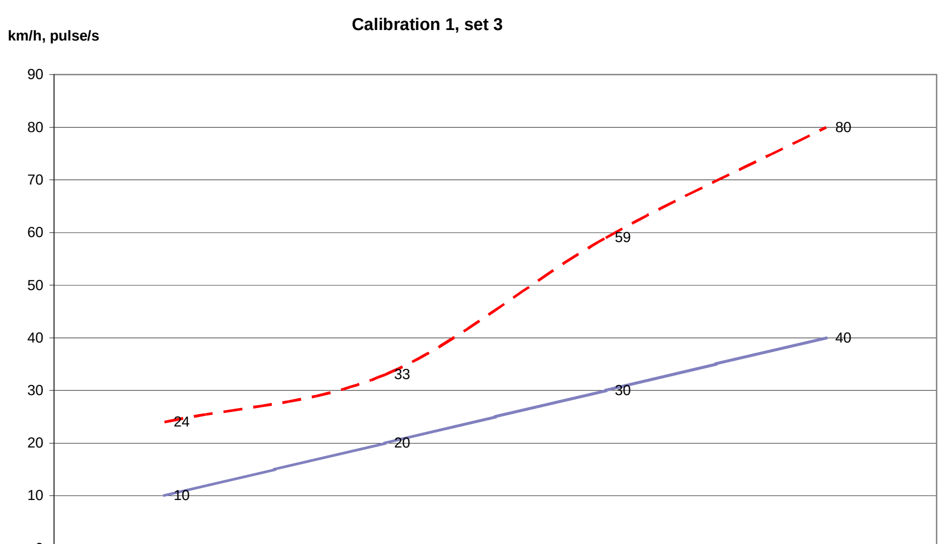


Figure 4.1 Calibration 1, set 1 graph



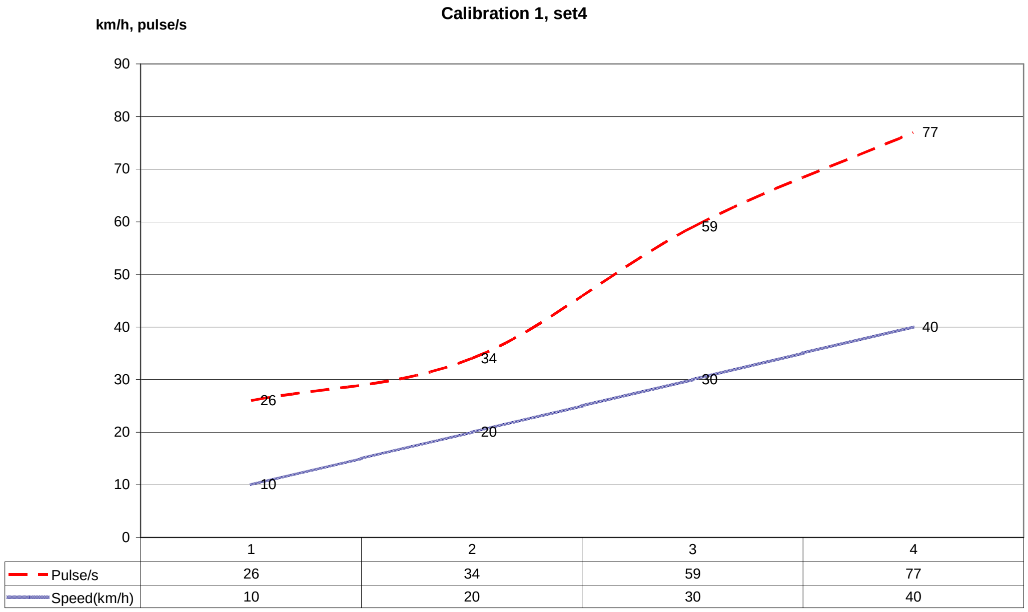
	1	2	3	4
Pulse/s	26	42	59	82
Speed(km/h)	10	20	30	40

Figure 4.2 Calibration 1, set 2 graph



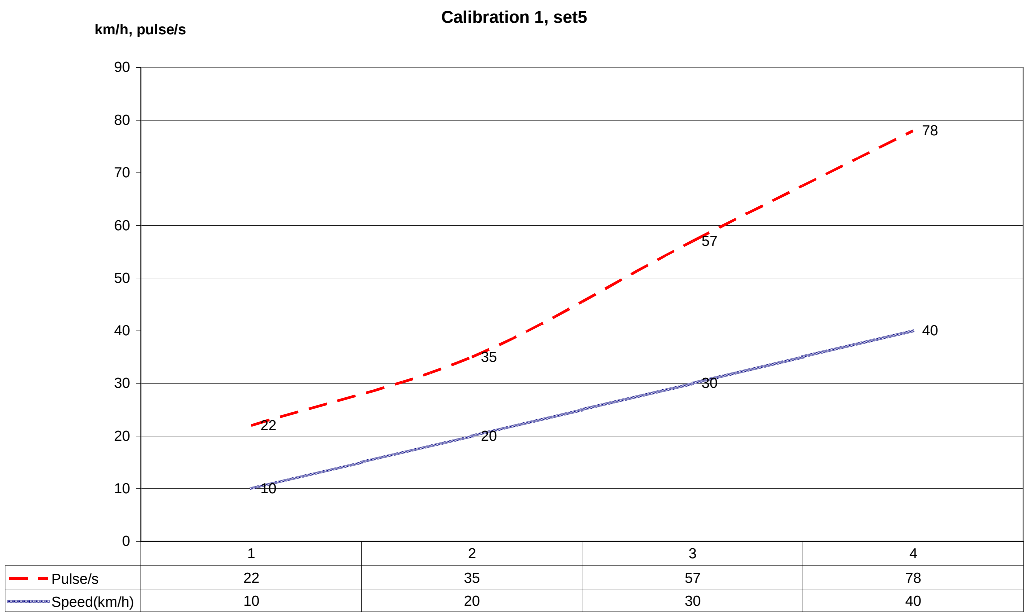
	1	2	3	4
Pulse/s	24	33	59	80
Speed(km/h)	10	20	30	40

Figure 4.3 Calibration 1, set 3 graph



	1	2	3	4
Pulse/s	26	34	59	77
Speed(km/h)	10	20	30	40

Figure 4.4 Calibration 1, set 4 graph



	1	2	3	4
Pulse/s	22	35	57	78
Speed(km/h)	10	20	30	40

Figure 4.5 Calibration 1, set 5 graph

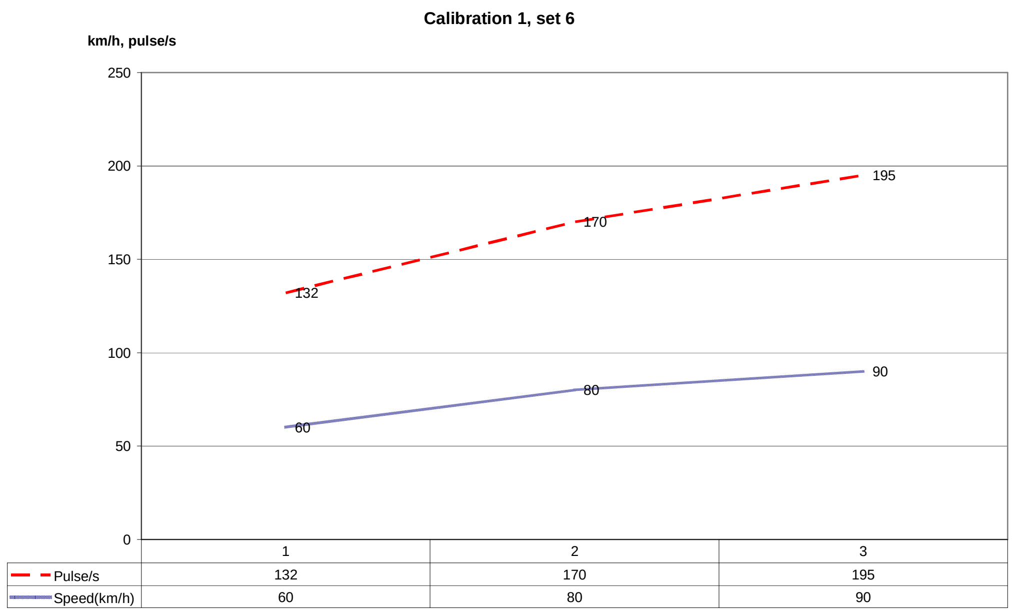


Figure 4.6 Calibration 1, set 6 graph

From the graph, we can see the linearity of the output of wind speed sensor and the constant speed of car even in the high speed calibration. A scaling value can be obtained from the values of speed for 1 pulse. The average speed for 1 pulse is calculated from the result and the value is 0.4857 km/h. The rounding value to 2 decimal points is 0.5 km/h. The speed for 2 pulses is 1 km/h. Since the BASIC language cannot support other than integer, the wind speed meter can only be read with resolution of 1 km/h. Because of that reason, the scaling factor is 2. From the scaling value, the error can be calculated.

To calculate error, equation used is;

$$\frac{\text{(average speed - average calibrated speed)}}{\text{average speed}} \text{ X } 100$$

The average speed used for the calibration process is <u>31.74</u>

The average calibrated speed value is <u>32.80</u>

The error is <u>3.36%</u>

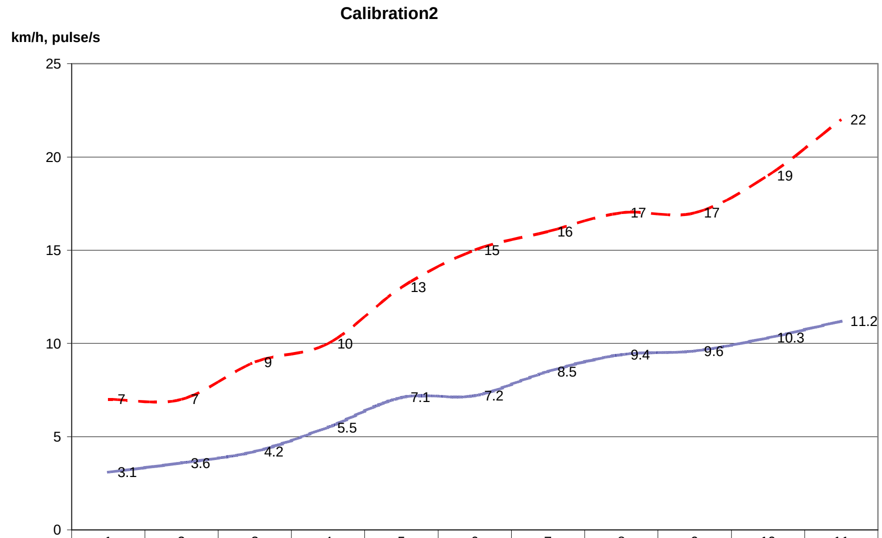
4.3 Calibration Method 2

For more satisfaction in determining the sensor accuracy, another method of calibration was conducted. It compares the output of the wind speed sensor with the real anemometer. As discussed in previous chapter, the anemometer is placed side by side to the wind speed sensor. Both sensors are pointed to wind source such as fan and both readings are taken.

The result shown in table below;

Table 4.7 Result for calibration 2 conducted on 10:00 p.m 30/10/2007

Anemometer (km/h)	Pulse/s
3.1	7
3.6	7
4.2	9
5.5	10
7.1	13
7.2	15
8.5	16
9.4	17
9.6	17
10.3	19
11.2	22



	1	2	3	4	5	6	7	8	9	10	11
Pulse/s	7	7	9	10	13	15	16	17	17	19	22
Anemometer (km/h)	3.1	3.6	4.2	5.5	7.1	7.2	8.5	9.4	9.6	10.3	11.2

Figure 4.7 Calibration 2, set 7 graph

From thegraph, by comparing the output on anemometer and the wind speed sensor, we can see the linearity of both devices. From the output value, the average value for speed of 1 pulse is 0.5 km/h. Which means 2 pulses equal to 1km/h. Therefore, the scalling value is 2, equal to previous calibration method.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Nowadays, wind speed meter and wind direction vane can be found in numerous types and sizes. The instruments are used in wide activities such as whether forecasting, sports, and even hobbies. The recent technologies have developed the wind instrument in a more complex method and the wind instruments not only can be used to measure the speed or direction but also to do more tasks such as humidity sensing and visibility sensing. For example, the sonic anemometer which use ultrasonic wave to measure wind speed in a 3 dimension direction.

This project's objective is to develop a digital wind speed meter with wind direction. The most suitable wind meter type is the aerovane type wind meter which includes both speed and direction sensing in one instrument. It is an open loop system. The main controller used is PIC 16F877A microcontroller from Microchip. The controller will gather output from speed and direction sensor. Both inputs will be processed and then provide output to LCD. The LCD will display the value of the calibrated speed and the direction of the measured wind.

In conclusion, both speed and direction sensors work fine and the LCD can perfectly display both speed and direction values. The objective and scope of the project is successfully fulfilled.

5.2 Problems

Some of the initial scopes have been found not suitable for this project due to the cost involved and practical consideration. The direction sensing was one of them. Initially, the direction sensing is planned to be used with absolute rotary encoder. The absolute rotary encoder encodes the direction into bits stream. Thus, it will be easier to program the microcontroller and the direction can be determined in angle values. However, the price for the encoder is too expensive as it is not developed for low cost instruments and small applications. The cheaper absolute rotary encoders are not suitable for this project as it is does not support high speed rotation and cannot endure the rotation pattern of the wind vane. It is also high in friction which is the main reason why it cannot be implemented in this project. For replacement, a potentiometer is used, which will give output in analog signal. We have to convert it to digital value for programming purpose. The PIC 16F877A have the analog to digital module and this solves the problem.

The tail on the anemometer is an important part for direction sensing. The tail will respond to the wind flow and the direction sensor can detect the change in wind direction. Tail design must maximize the blowing wind effect and sensitive too. Failure of the tail can bring error in speed sensing. Because of this, the tail design has been identified as a top priority on this project. Few designs have been experimented to ensure the design can be implemented. Weight and size of the tail are the main factors of the functionality of the wind vane. The aluminium is a light weight metal and therefore it is suitable for the tail. 20mm PVC conduit pipe has been used for tail arm.

5.3 Recommendation

Overall, the wind speed meter with wind direction system performance can be considered good. However, for high level accuracy system, many aspects in designing sensor, aerovane model and programming the PIC must be taken into a more proper ways.

For future development, some recommendations have been listed based on the problem encountered and unaffordable ideas.

i. Higher speed sensor resolution

For better speed sensing, the sensor should be more sensitive in detection even a slight flow of the wind. For this project speed sensor, the resolution is only 1 pulse per rotation of propeller. Increasing the resolution can increase the sensitivity of the sensor. To increase the speed sensor resolution, more permanent magnets should be attached on the propeller. The Hall Effect sensor will detect more magnet and more sensor output transitions will occur in a rotation of propeller. However, the placing of the permanent magnet must be distributed equally for the 360° of the propeller. Otherwise, the resolution will not uniform.

ii. No deadband potentiometer or heavy duty rotary encoder used for direction sensing.

Potentiometer used in this project has a huge drawback for the system. The deadband changes the initial scope of this project to display the direction in degree value because when the wind direction is on the deadband area, the value of angle cannot be obtained. Subsequently, the angle detection is not practical for this situation. Specific direction is more practical as it covers some angle for a certain direction. The dead band area can be replaced with a direction in microcontroller programinng and when potentiometer move to the deadband area, the value of the direction can be determined. Because of this, a full rotation potentiometer with less or no deadband is required. For a more accurate and easier programming approach, heavy duty rotary encoder should be taken into consideration. Even though the price is high, the application is lead to amore accurate direction sensing because the output is already in digital and processing it in microcontroller is easier and faster.

iii. Programming in more flexible language

BASIC programming language is a high level language for programming the PIC. However it does not cover all the features of programming plus the limitations reduce the complexity of developed system. Some of the features which affects the project are no support for string handling capabilities and only works with integers. Because of that, the speed value is only can be display in integer and no decimal point. The current system resolution is reducing because of that. The speed value can only be incremented in integer value only. Using the C language will solve the problem; however it will raise the complexity of the programming.

iv. More accurate modeling and fabrication

The modeling and fabrication is important for accuracy and quality of a project. Material used can determine the endurancy of the project from it application. For future development, all aspect of modeling and fabrication should be taken into more engineered ways. From modeling design to fabrication, proper tools or machine required must be used. For this project, the modeling is design and fabricated by experimenting with every design and it is not cost effective.

v. Data logging system

Data logging is a system to log the input or output data of a system. The data or record is stored and the analysis can be easily done rather than record it manually. For this project, the PIC 16F877A can be interface with computer. A wind analysis program in computer should be developed to monitor and analyse the wind speed and direction data. The wind speed and direction pattern can be known from the generated graph or table from the computer.

vi. Protection

If this instrument is to be used in open area such as field or on top of a building, lighting protection must be considered. The body must be plant and grounding properly to avoid it collapsing during storm or heavy rain and draw lighting to ground. Sealing the join is also a must before the instrument can be used in open area.

vii. Self powered device

For continuous functionality, a non-stop power supply should be considered. For example, self charging battery-solar power supply system can be implemented for this project to have it run continuously.

viii. Wireless data transmission

Sometimes, cabling can be a problem when the devices need to be connected is far away or the cable route is messy. To solve this, wireless transmission can be used. The wireless data transmission can be implemented in this project if the wired system brings difficulties to be applied in some areas. Wireless system will also reduce the after use problem such as wire break, corroded connector and so on.

5.4 Costing and Commercialisation

The cost to develop one unit of this project is summerised in the table below;

Table 5.1 Cost for controller

Unit name	Component	Qty	Price/Qty(RM)	Total Price (RM)
Controller	PIC 16F877A	1	30.00	30.00
	40-pin IC holder	1	1.00	1.00
	20MHz cystal	1	5.00	5.00
	LM7805	1	2.00	2.00
	Heat sink	1	1.50	1.50
	16x2 characters LCD	1	30.00	30.00
	Resistor 10 kΩ	6	0.10	0.60
	Resistor 1 kΩ	1	0.10	0.10
	Resistor 330R	1	0.10	0.10
	Resistor 100R	1	0.10	0.10
	Capacitor 22 pF	2	0.20	0.40
	Capacitor 10 μF	1	0.15	0.15
	Capacitor 0.1 μF	2	0.10	0.20
	IN4007	1	0.50	0.50
	LED	1	0.30	0.30
	Push-on switch	2	0.30	0.60
	Main switch	1	2.00	2.00
	Power supply jack	1	2.00	2.00
	Strip board	1		
			TOTAL	**76.55**

Table 5.2 Cost for cabling and connectors

Unit name	Component	Qty	Price/Qty(RM)	Total Price (RM)
Cabling and connector	DB15 male	2	3.00	6.00
	DB15 female	2	3.00	6.00
	2m 11-conductor cable	1	4.00	4.00
	10 strands rainbow cable	1	6.00	6.00
	Wrapping wire	1	15.00	15.00
			TOTAL	**37.00**

Table 5.3 Cost for speed sensor

Unit name	Component	Qty	Price/Qty(RM)	Total Price (RM)
Speed Sensor	A3144-Hall Effect IC	1	4.00	4.00
	Resistor 1 kΩ	1	0.10	0.10
	Capacitor 20 pF	1	0.20	0.20
	7.5 cm diameter brushless DC fan with ball bearing	1	15.00	15.00
			TOTAL	**19.30**

Table 5.4 Cost for direction sensor

Unit name	Component	Qty	Price/Qty(RM)	Total Price (RM)
Direction sensor	Potentiometer 10 kΩ	1	2.50	2.50
	20mm PVC pipe connector	1	0.50	0.50
			TOTAL	**3.00**

Table 5.5 Cost for Aerovane model

Unit name	Component	Qty	Price/Qty(RM)	Total Price (RM)
Aerovane model	Umbrella stand	1	18.00	18.00
	0.9m 3cm-diameter pillar	1	8.00	8.00
	Ball bearing	2	3.00	6.00
	Shaftt	1	7.00	7.00
	20mm PVC conduit pipe	1	2.00	2.00
	Alluminium plate	1	5.00	5.00
	20mm PVC pipe connectors	10	0.50	5.00
			TOTAL	**51.00**

Table 5.6 Overall cost for one set of digital wind speed meter with wind direction

Unit name	SubTotal Price (RM)
Controller	76.55
Cabling and connector	37.00
Speed Sensor	19.30
Direction sensor	3.00
Aerovane model	51.00
TOTAL	**186.85**

This project can be comercialised as wind speed meter with wind direction for whether instrument. It is suitable to be used in open areas such as fields, highways, and also on top of a building. However, due to its size, it might not be suitable for indoor use.

The production cost for this project is considered low because the materials used in this project are gathered from local shop. For mass production, lower production cost will be achieved by buying the materials in bulk quantity. Using an appropriate production machine to mass produce the product also will reduce the overall cost.

The prospect of this project is wide. It can be implemented for educational purposes, wind analysis, and even for personal hobby.

REFERENCES

1. Anemometer, available at:
   http://en.wikipedia.org/wiki/Anemometer

2. Allegro microsystems. *3141 thru 3144 sensitive hall-effect switches for high-temperature operation datasheet*.

3. Rotary encoder, available at:
   http://en.wikipedia.org/wiki/Rotary_encoder

4. WL2pe and BASIC Stamp to anemometer,(c) 2006 EME Systems, Berkeley CA U.S.A. Available at:
   http://www.emesystems.com/OL2wind.htm#Wind_vane

5. Iovine John (2000). *PIC Microcontroller Project Book*. 2nd Edition. Singapore: Mc Graw-Hill.

6. Lawrence A. Duarte (1998). *The Microcontroller Beginner's Handbook*. 2nd Edition. United States of America: Prompt Publication.

7. Microchip (2003). *PIC 16F877A datasheet*.

8. microEngineering Labs (2004), Inc. *PicBasic Pro Compiler*.

9. Dogan Ibrahim (2001). *PIC BASIC: Programming and Projects*.UK. Newnes

APPENDIX A

Programming on PIC 16F877A for digital wind speed meter with wind direction system

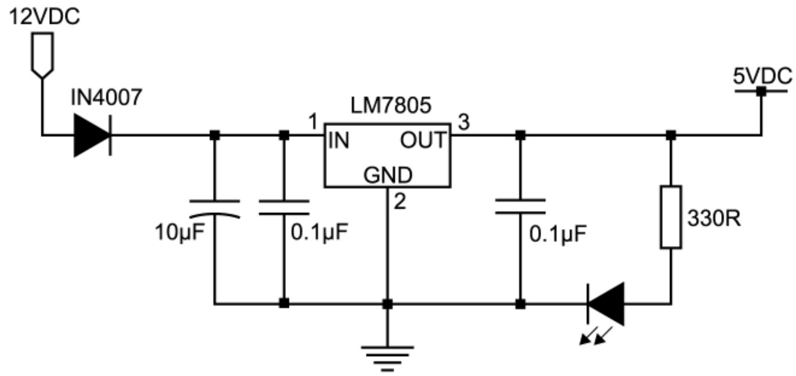
```
'**************************************************************
'*    Author     : Mohd Mokhtar Bin Ismail                     *
'*    ID         : ED04033                                     *
'*    Title      : PFKE 113: Digital Wind Speed Meter with     *
'*                 Direction                                   *
'*    Supervisor : Muhamad Zahim Bin Sujod                     *
'*    Date       : 31/10/2007                                  *
'*    Version    : 1.0                                         *
'*    Notice     : Copyright (c) 2007 UMP_PSM_2007             *
'*               : All Rights Reserved                         *
'**************************************************************

DEFINE OSC 20       'Using 20MHz crystal

DEFINE  LCD_DREG        PORTD   'LCD data port
DEFINE  LCD_DBIT        0       'LCD data starting bit 0
DEFINE  LCD_RSREG       PORTB   'LCD register select port
DEFINE  LCD_RSBIT       7       'LCD register select bit
DEFINE  LCD_EREG        PORTB   'LCD enable port
DEFINE  LCD_EBIT        5       'LCD enable bit
DEFINE  LCD_RWREG       PORTB   'LCD read/write port
DEFINE  LCD_RWBIT       6       'LCD read/write bit
DEFINE  LCD_BITS        8       'LCD bus size 8
DEFINE  LCD_LINES       2       'Number lines on LCD
DEFINE  LCD_COMMANDUS   2000    'Command delay time in us
DEFINE  LCD_DATAUS      50      'Data delay time in us


CNT     var WORD
UPDATE  var byte
PULSE   var BYTE    'Pulse count
ANGLE   VAR BYTE    'Angle detection
SPEED   VAR BYTE    'Calibrated value
SCALE   con 2       'Scale value

TRISA = %11111111   'Set PORTA to all input
TRISB = %00000001   'Set port B as output except bit.0
TRISD = %00000000   'Set port D as output
low     PORTB.6     'Set the R/W bit to low

OPTION_REG = 2      'Use prescaler 1:8
INTCON = %10110000  'Enable ext INT and TMR0 INT
ADCON0 = %11000001  'Configure ADC operation
ADCON1 = %00000000  'Configure ADC port-pin function
```

```
INTRO:  pause   1000                            'Wait until the
                                                 LCD initializes
        Lcdout  $FE, 1                          'Clear LCD screen
        LCDOUT  $FE,$80," Wind Speed and "      '1st line-display
                                                 title
        LCDOUT  $FE,$C0,"Direction  Meter"      '2nd line-display
                                                 version
        pause   3000
        Lcdout  $FE, 1                          'Clear LCD screen
        LCDOUT  $FE,$C0,"     V 1.00"           '2nd line-display
                                                 version
        pause   1000
        LCDOUT  $FE,$C0,"    PSM 2007"          '2nd line-display
                                                 title
        pause   1000
        LCDOUT  $FE,$C0,"     U M P  "          '2nd line-display
                                                 UMP
        pause   2000
        Lcdout  $FE, 1                          'Clear LCD screen

        TMR0 = 131
        INTCON=$A0                      'Start timer
        cnt=0
        PULSE = 0                       'Clear pulse
        angle = 0                       'Clear angle
        INTCON.1=0                      'Clear ext INT flag
        INTCON.2=0                      'Clear TMR0 INT flag
        On INTERRUPT GOTO ISR           'Interrupt service routine


LOOP:   IF  UPDATE=1 THEN
            UPDATE=0
            SPEED=PULSE/SCALE
            ADCIN 0, angle
            LCDOUT $FE,1
            'Display speed value on 1st line
            LCDOUT $FE,$80,"SPEED   ",DEC3 SPEED," km/h"
            'Display direction value on 2nd line
            IF ANGLE>246 AND ANGLE<=255 THEN  LCDOUT $FE,$C0,
"DIRECTION   NE"
            IF ANGLE>199 AND ANGLE<=246 THEN  LCDOUT $FE,$C0,
"DIRECTION   E"
            IF ANGLE>151 AND ANGLE<=199 THEN  LCDOUT $FE,$C0,
"DIRECTION   SE"
            IF ANGLE>104 AND ANGLE<=151 THEN  LCDOUT $FE,$C0,
"DIRECTION   S"
            IF ANGLE>56  AND ANGLE<=104 THEN  LCDOUT $FE,$C0,
"DIRECTION   SW"
            IF ANGLE>9   AND ANGLE<=56  THEN  LCDOUT $FE,$C0,
"DIRECTION   W"
            IF ANGLE>0   AND ANGLE<=9   THEN  LCDOUT $FE,$C0,
"DIRECTION   NW"
            IF ANGLE=0                  THEN  LCDOUT $FE,$C0,
"DIRECTION   N"
            PULSE = 0       'Clear pulse count
```

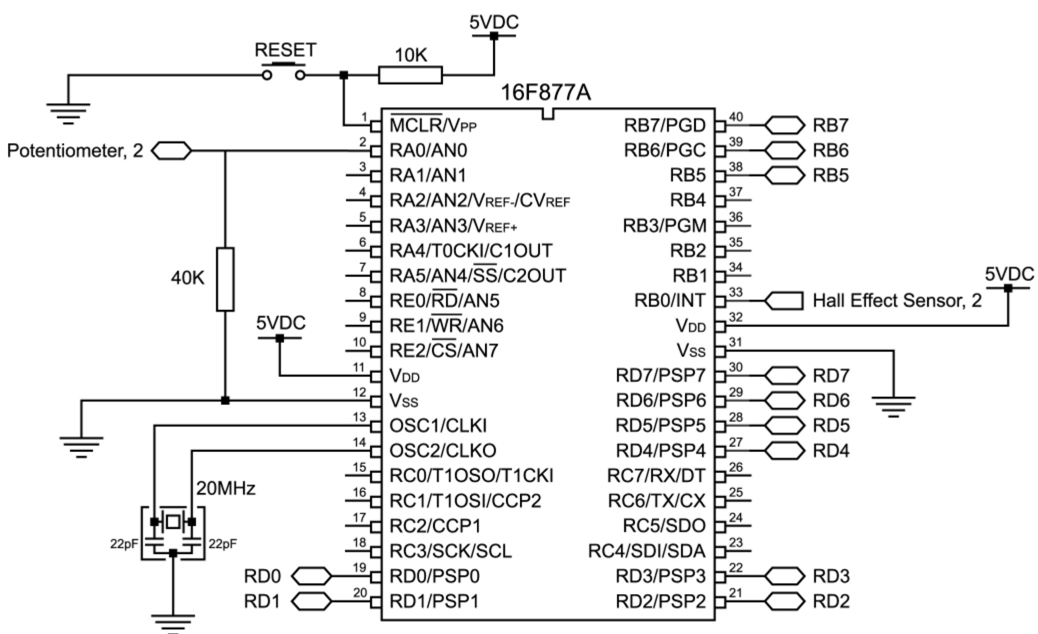
```
        ENDIF
        goto loop


disable                     'Interrupt handler
ISR:    if  INTCON.1=1 then
            pulse=pulse+1
            INTCON.1=0      'Re-enable INT interrupt
        endif
        if  INTCON.2=1 THEN
            cnt=cnt+1
        if  cnt<5000 then NOUPDATE
            update = 1
            cnt = 0
            INTCON.2=0      'Clear timer overflow flag
        ENDIF

NOUPDATE:   INTCON.2=0      'Clear timer overflow flag
resume                      'Return from interrupt
enable

END
```

APPENDIX B

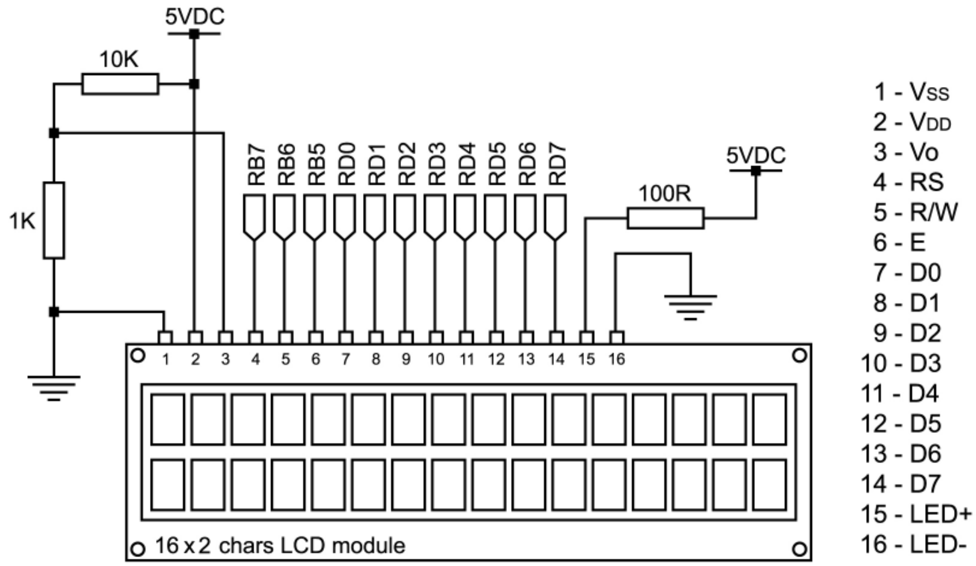
Overall project circuit



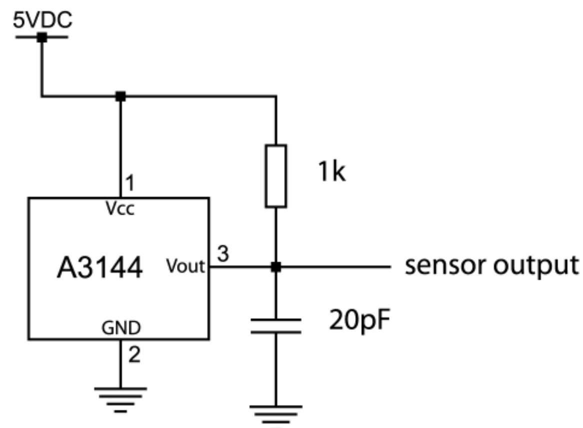
Circuit A Power suppl circuit for the whole project



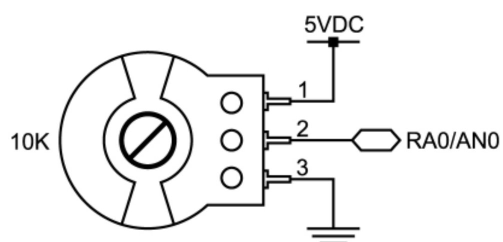
Circuit B Controller circuit



Circuit C LCD circuit



Circuit D Speed sensor circuit



Circuit E Direction sensor circuit

APPENDIX C

Datasheets