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DESIGN AND FABRICATION OF A LOW COST WIND VELOCITY METER

Muhammad Asad Rahman[2], Mokarrom Hossain[3], Sampad Ghosh[4] and Mohammad Rafiqul Alam[1]

[124]Dept. of Electrical & Electronic Engineering, Chittagong University of Engineering & Technology, Bangladesh
[3]Dept. of Electrical & Electronic Engineering, University of Science & Technology Chittagong, Bangladesh
mra_cueteee@yahoo.com[1], asad31@cuet.ac.bd[2], mhossain555@gmail.com[3], sampad04cuet@yahoo.co.in[4]

Abstract*- This project entails design and implementation of a wind velocity meter. Actually this is a mechatronics project. Since, both electrical and mechanical conceptions are used to implement this project. The Mechanical system consists of two physical subsections – wind vane and anemometer. Here wind van is used to detect wind direction and anemometer for wind speed measurement. Its hardware section includes the PIC microcontroller, IR sensor, photo detector etc to convert wind speed and direction into electrical means. The software component includes the program and code implemented via the PIC microcontroller. The microcontroller is used as a central controller to measure the speed and direction of the wind by taking the pulse from sensors. By using sensors, microcontroller calculates wind speed as well as detects wind direction and displays it on a 16 x 2 characters Liquid Crystal Display (LCD).*

Keywords: Anemometer, Wind vane, Microcontroller, IR sensor, Liquid Crystal Display

1. INTRODUCTION

Wind is a phenomenon caused by large moving masses of air molecules. These molecules comprise the gaseous atmosphere that surrounds our planet. Heat is the driving force behind the movement of air molecules in our atmosphere. Moving air masses (wind) are most often quantified in terms of their relative direction and velocity [1].

Wind must be playing an important role in the life of mankind. Because the type of weather we experience is closely linked to these moving air masses, a great deal of meteorological information can be gleaned from wind-speed and wind-direction measurements. Wind speed can also be an excellent indicator of current and future weather conditions. The information about wind speed and wind direction is also required in weather station, aviation, seaport etc.

Besides, wind energy can play a supportive role with conventional source of energy to produce electrical energy. So measurement of wind velocity is necessary in this purpose.

The two instruments commonly used to measure wind speed and wind direction are *The Anemometer* (wind speed) and *The Wind Vane* (wind direction) [1].

In fact, '*Velocity*' is a vector quantity that means its true representation needs both information about speed and direction. So the aim of this project is to design and implement a system that can be used for measuring wind speed and able to indicate the direction of wind. Moreover this system stores maximum measured wind velocity during the monitoring period to help anyone to know maximum value further later.

Since a help is taken from mechanical arrangement to measure wind velocity, so weight and friction are also the important limitation for this project. If weight increases, then the friction also increases into its rotational parts. That's why it is necessary to implement this mechanical section using low weight materials such as plastic, aluminum.

2. MATHEMATICAL MODEL FOR WIND SPEED MEASUREMENT

A pulse is received after 360° rotations.

Consider a cup anemometer rotating at speed ω in a free wind speed V shown in Fig. 1:

The instantaneous aerodynamic torque on the rotor, M_A, is given by:

$$M_A = \frac{1}{2} r\rho AC_{dv}(V - r\omega)^2 - \frac{1}{2} r\rho AC_{dx}(V + r\omega)^2 \qquad (1)$$

Where A is the frontal area of the anemometer, ρ is the air density, C_{dv} and C_{dx} are the drag coefficients for the concave and convex faces of the anemometer cup and r is radius of the circle formed by three semi conical cups.

In the steady state, there is perfect torque balance ($M_A=0$), and the Eq. (1) reduces to:

$$C_{dv}(V - r\omega)^2 = C_{dx}(V + r\omega)^2$$

Defining μ as the drag ratio, $\mu = \dfrac{C_{dv}}{C_{dx}}$

$$\mu^2 = \frac{V + r\omega}{V - r\omega}$$

$$\text{or, } V = \frac{\mu^2 + 1}{\mu^2 - 1} * r\omega \qquad (2)$$

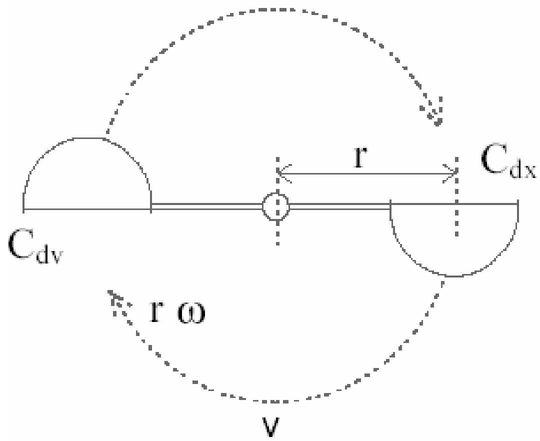

Fig.1: Rotating anemometer showing different parameter

Typical values of C_{dv} and C_{dx} are 1.4 and 0.4 respectively, giving a value of μ of 3.5 [2]. Then Eq. (2) is

$V = 1.18 * r\omega$

Or, $V = 1.18 * r * 2\pi N$ cm/sec

Where N = no. of rotation/sec & $\omega = 2\pi N$ [3]

Or, $V = 7.41 * r * N$ cm/sec (3)

For this project the value of r is 10 cm. Here as the value of N is variable so after measuring the value of N, speed of wind (V) can easily be calculated using Eq. (3).

3. SYSTEM OVERVIEW

This project is a mechatronics project where both electrical and mechanical conceptions are combined. The Mechanical system consists of two physical subsections – wind vane and anemometer.

Figure 2 shows the whole arrangement of the system by means of block diagram.

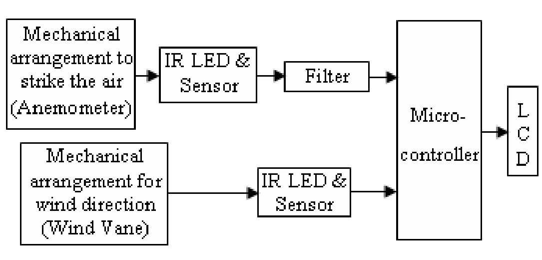

Fig. 2: Block diagram of Wind velocity meter

Wind vane is a weighted pointer connected to a small flat plate and is attached to a rotating vertical shaft. A metal arm is connected to this vertical shaft that cuts and exposes the IR sensors alternately. Eight IR sensors are used to detect direction. So the direction of wind is measured by pulse received from IR sensor, when the wind direction changes.

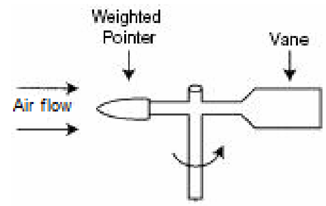

Fig.3: Wind vane

In anemometer, three semi conical cups are mounted on an axis to rotate freely in the wind. The pulse from IR sensor, whose light is blocked periodically by the rotating arm that is connected to axis, can be used to measure the rotation speed that is proportional to the wind velocity.

In electrical section, the microcontroller is used as a central controller to measure the speed and direction of the wind and displays it on a 16 x 2 characters Liquid Crystal Display (LCD). From the number of measured pulses per sec, the speed is calibrated for displaying the value of wind velocity.

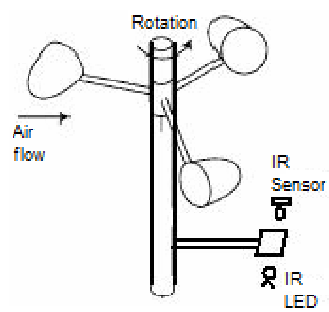

Fig.4: Anemometer

4. DESIGN AND IMPLEMENTATION

4.1 Mechanical Section

During design and implementation of a sensitive mechanical arrangement to measure wind speed and detect wind direction, it demands the following requirements: The anemometer including cup assembly should be small, it should be sensitive; that is, it should have a low turning force and a quick response to wind speed, it should have a linear response [4]. So to fulfill the above requirement, the mechanical structure should have low weight and friction less though it cannot be made frictionless.

From different literature and journal, it found that the 3-cup anemometer system yields a more uniform torque and a greater torque per unit weight than 2- or 4-cup systems [4]. The relation between cup speed and wind speed will be linear when the arm length is 2.5 times the cup radius. This criterion prevails in commercially available anemometer [4].

Three conical-shaped cups are used to implement anemometer that are made by plastic. A 14cm Aluminum Rod needs to fit the cup horizontally with vertical shaft and a 10cm Aluminum Rod used as shaft. A ball bearing is used to tight fit the shaft so that it can rotate freely. Figure 5 illustrates cup arrangement and all dimensions.

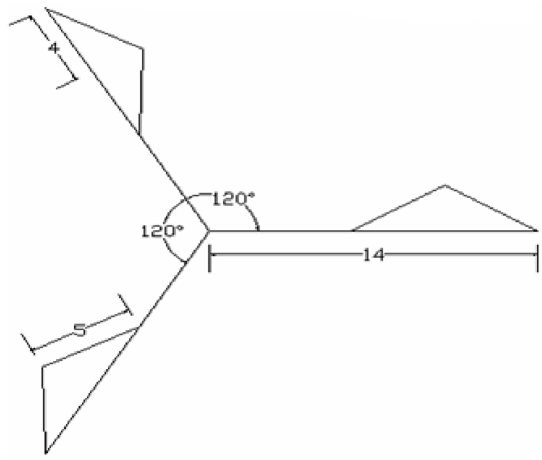

Fig.5: Design of mechanical structure for wind speed measurement

To implement the wind vane, a weighted pointer connected to a small flat plate is made of plastic material. A 4cm Aluminum plate needs to fit the flat plate horizontally with vertical shaft and a 13cm Aluminum Rod used as shaft. This shaft is tight fitted using a ball bearing. Wind vane design is shown in Fig.6.

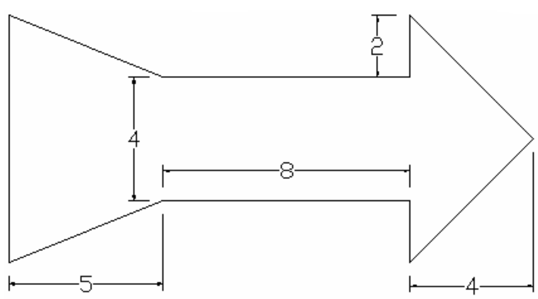

Fig.6: Design of mechanical structure for wind direction detection.

4.2 Electrical Section

Wind speed measuring circuit is shown in Fig.7. IR photo diode in this circuit is used to detect light from IR LED. A photo diode normally shows high resistance when no light falls on it and at light it shows low resistance. When light fall on photo diode, almost full voltage drop across 100k-ohm resistor. So a high pulse is detected by microcontroller. When no light falls on photo diode, input in microcontroller is low.

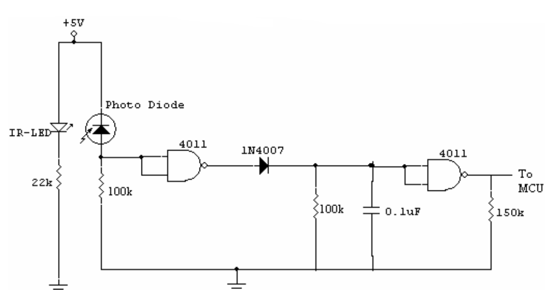

Fig.7: Circuit arrangement for wind speed measurement

The circuit diagram for wind direction is shown in Fig.8. This transmitter part is made by using a LED that radiates light to a light dependent resistor (LDR). The resistance of LDR depends upon light. When light fall on LDR, resistance of LDR fall and a low pulse is detected by microcontroller. When no light fall on LDR, the reverse action occurs.

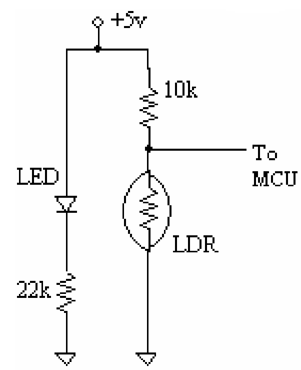

Fig.8: Circuit arrangement for wind direction diction

Figure 9 below shows the connection diagram of microcontroller. PIC16F877A microcontroller is used. It consists five I/O ports [5]. These I/O ports are recognized by Port A (RA0-RA5), Port B (RB0-RB7), Port C (RC0-RC7), Port D (RD0-RD7) and Port E (RE0-RE2). Port C (RC0-RC7) is used to receive input pulse from receiver circuit use for eight directions. RD0 of Port D is used to receive pulse from receiver circuit, which is used for wind speed measuring purpose. By taking these signals, microcontroller calculates wind speed and direction according to program loaded in its program memory.

Finally, the output comes through Port B (RB0-RB7). Port B is connected to a liquid crystal display (LCD) to show the output graphically. Port D (RD1-RD3) is used to give control signal to LCD.

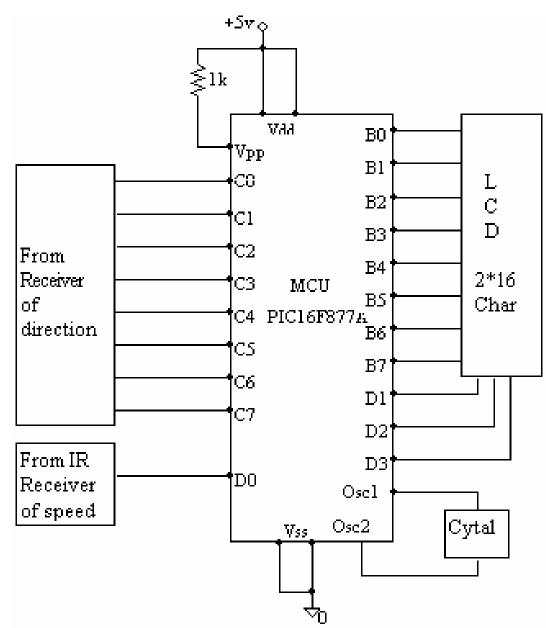

Fig.9: Microcontroller connection arrangement

Port C (RC0-RC7) of microcontroller is defined as input pin in program. These pins are used to receive pulse from wind direction circuit. By taking status of these pins, microcontroller determines the bit value of pins because each direction holds unique value. Value for each direction is given in Table-1. From these values, microcontroller takes decision about wind direction.

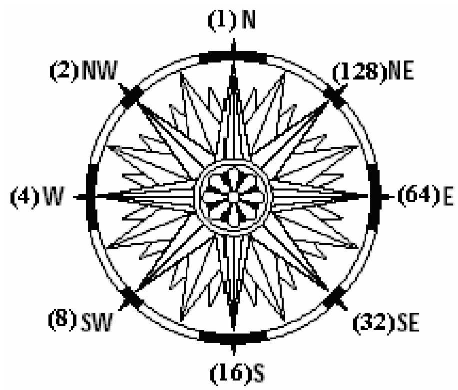

Fig.10: Direction Chart

4.3 Microcontroller Coding

The complete procedure of programming can be divided into main three steps [6]. First step is *writing the Basic language program*. Second and third step are *using the compiler* and *loading the compiled program into microcontroller program memory.*

Table 1: Coding for wind direction detection

N	N-W	W	S-W	S	S-E	E	N-E	Decimal value	Direction
1	0	0	0	0	0	0	0	1	N
1	1	0	0	0	0	0	0	3	N-W
0	1	0	0	0	0	0	0	2	N-W
0	1	1	0	0	0	0	0	6	N-W
0	0	1	0	0	0	0	0	4	W
0	0	1	1	0	0	0	0	12	S-W
0	0	0	1	0	0	0	0	8	S-W
0	0	0	1	1	0	0	0	24	S-W
0	0	0	0	1	0	0	0	16	S
0	0	0	0	1	1	0	0	48	S-E
0	0	0	0	0	1	0	0	32	S-E
0	0	0	0	0	1	1	0	96	S-E
0	0	0	0	0	0	1	0	64	E
0	0	0	0	0	0	1	1	192	N-E
0	0	0	0	0	0	0	0	128	N-E
1	0	0	0	0	0	0	1	129	N-E

To complete above three steps, *MicroCode Studio Plus* software is used. This software contains all three facilities in the same window. *MicroCode Studio Plus* software window is shown in Fig.11.

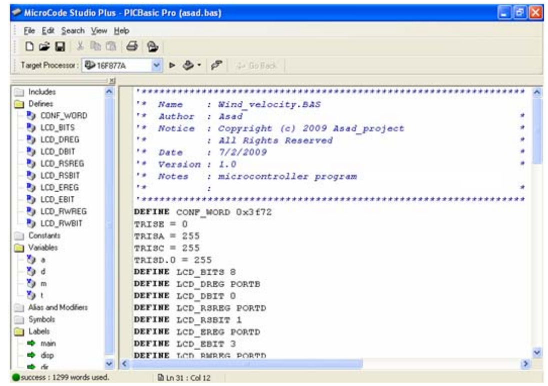

Fig.11: MicroCode Studio plus Program Window

After implementing the entire task mentioned above, finally proposed wind velocity meter is established that is shown in Figs.12~13.

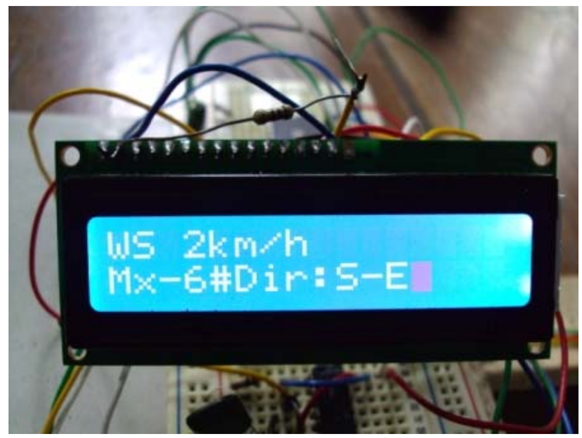

Fig.12: LCD output

Fig.13: Wind velocity meter after implementation

5. CONCLUSIONS

In this paper we have worked on each section and the complete system entirety functioned properly and successfully. Multipurpose of any equipment is the most desirable criteria in modern technology. Nowadays economic operation is another criterion for any equipment. So at the time of designing of this project, idea was gathered in such way that it can give several number of information. For this reason this project can be used to measure wind speed and to detect wind direction. Besides these, it also helps to store maximum wind speed for a certain period.

6. REFERENCES

[1] John Morley, “A wind speed and direction interface for the HCS II”, Home automation and building control, March 1999, pp53-62.

[2] S. Hunter, Raymond, “Wind Speed Measurement and Use of Cup Anemometry”, edition 1999, Renewable Energy Systems Ltd, pp 3 - 4, 33.

[3] Chambers Virgil, *Analytic Mechanics*, The Macmillan Company, 3rd ed., 1999, pp244-245.

[4] J. L. Fritschen, “A Sensitive Cup-Type Anemometer”, *Journal of Applied Meteorology*, Volume 6, pp 695-697.

[5] Microcontroller Documentation, Microchip Technology,<http://ww1.microchip.com/downloads /en/DeviceDoc/39582b.pdf>. (25-03-2011)

[6] John Iovine, *PIC Microcontroller Project Book: A true beginner’s guide to the popular PIC microcontroller*, McGraw-Hill, 2000.

7. NOMENCLATURE

Symbol	Meaning	Unit
M_A	Aerodynamic torque	Newton meter
ω	Angular velocity	radians/ Sec
V	Wind speed	m/Sec
A	Frontal area of the anemometer	m^2
ρ	Air density	Kg/m^3
C_{dv}	Drag coefficients for the faces of the anemometer cup	Dimentio-nless
C_{dx}	Drag coefficients for the convex faces of the anemometer cup	Dimentio-nless
r	Radius of the circle formed by three semi conical cups	c.m.
μ	Drag ratio	Dimentio-nless
N	no. of rotation	Rotation/ Sec