



Data Acquisition System for Wind Speed, Direction and Temperature Measurements

Dr. Fouad Sh. Tahir
Lecturer

Ayad M. Salman
Asst. Lecturer

Dr. Jabbar K. Mohammed
Lecturer

Wahab K. Ahmed
Engineer

Energy and Renewable Energies Technology Center
University of Technology
Iraq-Baghdad

Abstract:

This paper describes the use of microcomputer as a laboratory instrument system. The system is focused on three weather variables measurement, are temperature, wind speed, and wind direction. This instrument is a type of data acquisition system; in this paper we deal with the design and implementation of data acquisition system based on personal computer (Pentium) using Industry Standard Architecture (ISA) bus.

The design of this system involves mainly a hardware implementation, and the software programs that are used for testing, measuring and control. The system can be used to display the required information that can be transferred and processed from the external field to the system. A visual basic language with Microsoft foundation classes (MFC) is the fundamental tool for windows programming. It has been used to build a Man-Machine Interface (MMI), which was used for processing and monitoring acquisition data from environment weather.

الخلاصة

تتناول الدراسة الحالية توصيف لاستخدام الحاسوب كأداة مختبرية حيث تركز هذه المنظومة على قياس متغيرات الطقس كدرجة الحرارة وسرعة الرياح واتجاهها، إذ تمثل هذه الأداة المختبرية نوع من أنظمة استخلاص البيانات. لقد تناولت هذه الدراسة التعامل مع تصميم وبناء منظومة رقمية لاستخلاص البيانات تعتمد على الحاسوب الشخصي نوع (بنتيوم) من خلال استخدام معمارية الناقل الصناعي القياسي (ISA). يتضمن تصميم المنظومة بشكل رئيسي من بناء الكيان المادي والكيان البرمجي الذي يستخدم لأغراض الفحص والقياس والسيطرة. للنظام القدرة على عرض المعلومات المطلوبة والتي يتم نقلها ومعالجتها من الحقل الخارجي إلى داخل المنظومة. لقد تم استخدام لغة فبجوال بيسك المصنفة كأساس الميكروسوفت كأداة أساسية لبرمجة النوافذ. حيث استخدمت هذه اللغة لبناء الربط البيئي لرجل الماكينة (MMI) والذي استخدم للمعالجة ومشاهدة البيانات المستخلصة من الطقس.

1. Introduction

Data acquisition systems is an interfacing unit between the real world of physical parameters, which are analog, and the artificial world of digital computation and control. With current emphasis on digital systems, the interfacing function has become an important one; digital systems are used widely because complex circuits are low cost, accurate, and relatively simple to implement. In addition, there is rapid growth in the use of microcomputers to perform difficult digital control and measurement functions (Gerd 2005).

Sensors are essential components in many applications, not only in the industries for process control but also in daily life for building's safety and security monitoring, traffic flow measuring, weather condition monitoring and etc. In weather monitoring, for instance, parameters such as wind speed, wind direction and temperature need to be measured (\pm) thus sensors have always assigned the task for doing so.

Weather or climate plays an important role in human life. The thermal comfort of human being is known to be influenced mostly by six parameters, i.e., air temperature, radiation, air flow, humidity, activity level and clothing thermal resistance. The advancement in technology has made these small and reliable electronic sensors capable of monitoring environmental parameters more favorably (Kamarul and Chow 2006).

2. Type of Instruments for Wind Speed and Direction Measurement

The two instruments commonly used to measure wind speed and wind direction are the anemometer (wind speed) and the wind vane (wind direction).

2-1. Wind Direction Sensor

The wind vane, illustrated in Fig. 1, measuring wind direction sensors are generally some variant of the familiar weather vane. Sensitivity is maintained by constructing the weather vane to rotate on bearings with minimal resistance. Electronic readout can be achieved using a potentiometer (a "wiper" contact connected to the vane slides over a wire-wound resistor). The resistance between the contact and one end of the wire resistor indicates the position of the vane. Alternative methods of readout

include optical and magnetic position sensors. Positional accuracy is $\pm 5\%$ (John 2000).

2-2. Rotational Anemometer

Weather stations commonly employ a 3-cup anemometer. This consists of a vertical axis rotating collar with three vanes in the form of cups. The rotation speed is directly proportional to wind speed as shown in Fig.2. An alternative to the cup anemometer is a propeller anemometer in which the wind causes a propeller to rotate. There are several ways to obtain an electrical signal indicating the speed: a magnet attached to the rotating shaft can induce a sinusoidal electrical impulse in a pickup coil; a Hall effect sensor can be used; or the rotating shaft can interrupt a light beam, generating an electric pulse in a photo detector. Rotating anemometers can measure wind velocities from close to 0 up to 70 m s^{-1} (150 mph) (Ian 2001)

3. Integrated Circuit Temperature Sensor

This very cheap, simple means of temperature measurement or compensation for temperature in the range -40°C to $+110^{\circ}\text{C}$. The integrated circuit, which looks like a small transistor, operates on a power supply between 4 to 30 volts, giving a linear output of 10 mV deg./ $^{\circ}\text{C}$, with an accuracy of $\pm 0.4^{\circ}\text{C}$ (Telemetry Group 2005).

4. Computer Measurement and Control Hardware Requirement of the Present Work

The computer interface system hardware comprises mainly of the following unit:

- Input and output interface circuit.
- Data acquisition system.
- Transducer.

4-1. Input and Output System Hardware

The system hardware was designed and built for real time computer control and measurement operation. The designed process system is interfaced to (Pentium 1) microprocessor system via a group of buffering and latching gate, each having 8-bit I/O port which are used to adapt with other external hardware system as shown in the detailed interface circuit diagram of Fig.3 (Telemetry Group 2005 and K. Lacanette1997). The address that are used and the functions performed by each unit are mapped in Table 1.

4-2. Data Acquisition System

The data acquisition system was designed to transfer 8-bit data system variable (temperature, direction, and wind speed) to the microcomputer system.

An 8-bit, 8-channel unipolar (ADC0808) analog to digital converter based on successive approximation is used for measuring three different variable (wind direction, wind speed, and weather temperature) each one of the measured variable use a separated input channel in the analog to digital chip.

The data acquisition is started by selecting the required channel to be converted, the selector line come from one bit in the output port. The conversion is initiated by start conversion pulse that is applied from the computer through another bit of the same selector output port. Then the status of the A/D is read by means of input port to ensure the conversion is complete. The basic units of data acquisition system are interconnected as shown in details of **Fig.4 (D.C. Ramsay 1996 and Chuck Hellebuyck, 2003)**.

4-3. The Transducer (Gods Atul P., 2008 and Patil C. Y., 2008)

The wind-vane transducer shaft is internally coupled to 20k Ω potentiometer for measuring shaft position and wind direction; this potentiometer has a complete 360° rotation with no rotation stop.

The anemometer shaft is internally coupled to magnetic reed switch. Each revolution of the anemometer produces one contact closure of the reed switch.

The data acquisition system has a number of 8-analogue channels inputs designed to be connected to analogue type measurement sensor. Other analog inputs can be added if we use network modules, these analog inputs are designed to interface to ground-referenced (0-5) VDC analog signals. The interfacing is capable of measuring the frequency of a periodic input signal (digital) with the accruing required for this interface. To be compatible with interface analog input, a signal is needed that varies from 0 to 5 VDC and is proportional to wind direction. The wind-vane shaft is directly connected to the wiper of 20-k potentiometer. Therefore the position of the pot wiper always indicates wind direction.

It's a simple matter to connect the ends of the potentiometer to ground and to +5VDC. The wiper voltage then varies from 0V(0 degree) to 5V(360 degree) as the wind vane is rotated. The

relationship between the wiper output voltage and wind direction can be determined by:

$$\text{Wind Direction} = \frac{V_{\text{out}}}{5V} \times 360^\circ \quad (1)$$

This relationship assumes that the potentiometer is completely linear. The first step in the design of the wind speed interface is to calibrate the anemometer to correlate wind speed versus switch-closure frequency. To accomplish this step, we mounted the wind transducers to the spare tire carrier at the rear of our truck. Then, we drove the vehicle on a virtually windless morning at speeds spanning the input range of the anemometer while measuring the switch-closer frequency. Before attempting this experiment we also had our vehicles speedometer professionally calibrated since our new tire diameter differed from the original tires. The recalibration resulted in a fixed indicted speed offset of about +3MPH. The results of our data collection which has measured experimentally are presented in **Fig.5**. The manufacturer subsequently verified our finding-one switch closure per second (or 1 Hz) equaled 2.33MPH. Thus, over the wind speed range of interest (0-115MPH) the switch closure frequency varies from (1Hz=2.3MPH) to (50Hz=115MPH).

There are many ways to convert a variable frequency signal in to DC voltage. This type of circuit, often known as a tachometer circuit is implemented most often using a single-chip FN converter integrated circuit. The circuit consists of an input comparator, one-shot, and integrator.

Each time the input signal crosses the comparator threshold; it activates the one-shot, which switches a precise amount of charge in to the integrator input for a measured time period. As the input signal increases in frequency, the charge injected into the integration capacitor increase proportionally. The result is an average output voltage from the integrator proportional to the input signal frequency.

Obviously, this job was better suited to a digital counter or micro controller. We choose microchips PIC16C54 due to the circuit designs simplicity, low parts count, and program flexibility. In the approach we followed, the wind speed transducer is connected directly to an input bit of the PIC micro-controller.

An 8-bit D/A configured for an output range 0-5 volts DC is connected to eight of the PIC general-purpose I/O bits, which are configured as outputs.

To measure wind speed, the PIC simply counts the number of anemometer switch closures during a predetermined time period (frequency). This count is then scaled to obtain the 8-bit digital value, which drives the DAC. The scale factors ensure that the digital output is equal to 225 when the input frequency is equal to 50 Hz (115 MPH).

The DAC output voltage is always proportional to the wind speed as measured by the anemometer. The software programmed to measured frequencies up to 50 Hz in 1Hz increments. Thus, wind speeds up to 115 MPH can be measured in increments of 2.3 MPH. Therefore, at a wind speed of 0 MPH, the output voltage of the circuit is 0 volt, and it is 5 volt with a wind speed of 115 MPH.

The relationship between the DAC output voltage and wind speed can be found by the following equation:

$$windspeed = \frac{V_{out}}{5V} \times 115 \quad (2)$$

By using a micro-controller, we can measure switch closure frequency (and thus, wind speed) with greater resolution than 1 Hz. in our application, however, this level of precision was unwarranted. The circuitry required to interface the wind speed and direction transducers is shown in Fig.6.

For weather temperature measurement we need a transducer to sense this temperature. For our work we use LM334 a three terminal adjustable current source, as a temperature sensor because it is reliable, economical and compact in size. The output current I_{set} of the LM334 is directly proportional to absolute temperature in Kelvin (k) and is given by

$$I_{set} = \frac{(227uv/k)(T)}{R_{set}} \quad (3)$$

where:

I_{set} = output current of the LM334.

R_{set} =resistor that determines I_{set} and is connected between R and V terminals of LM334.

T=temperature in Kelvin.

To express the output voltage V_o of the LM334 in terms of I_{set} and R_L we will use the connection diagram of the LM334 shown in Fig. 7. And equation (3). In other words the output voltage will be.

$$V_o \approx I_{set} R_L$$

$$V_o \approx 10m V / K \quad (4)$$

To condition the output signal of the temperature transducer to make it suitable for the ADC o8o8 we will use a voltage follower and differential amplifier as shown in Fig.8. Because the voltage follower eliminate loading and differential amplifier provides the gain necessary to make the signal suitable for the ADC.

5. System Software (Barry B. Brey, 2007)

The software of the system consists of two main parts: Man-Machine Interface software and control software. Man-Machine interface software is application independent. And it plays the role of an interface between the operator and the system. While the control software is application dependent and must be written specially for the used control hardware (plug-in card).

The control software is lightly linked to the Man-Machine interface software, and the two must be worked together to make the system software function. The system software was implemented by using visual basic language, which is fundamental programming for windows. We deals with visual basic software programming because it is easy to use and has a speed adequate for most application (the exception is control of the analog-digital-converter, a process which requires precise timing).

The program begin with an initialization procedure which configures the computer for the correct channel of the variable measurements, setup the necessary data array-and performs other housekeeping chores. The user is then given the opportunity to plot data stored on a hard-disk from a previous measurements, or to run the operation of measurement itself, if the user chooses to begin the measurement task the program immediately goes in to the data acquisition software which acts as controller, prompting other program which collect the data, manipulated data, and display the variables on user window as a real value or display it as graphics. The user window which represent the Man-Machine interface software is shown in Fig. 9.

The procedure represents the main program which was used to initialize the procedure of measuring the weather variables is illustrated in following steps:

- 1- Start.
- 2- initialize the input ports of the system.
- 3- select the digital to analog (ADC) input port.
- 4- Send start conversion signal to ADC unit.



- 5- Check the ADC status , If it is true then end the conversion operation and input the binary data to the computer system and go to step 6 .Else take few second and return to check the ADC status.
- 6- Manipulated the digital raw input data.
- 7- save the information in specific array on hard disc and display the weather variable on the user window.
- 8- If you want to repeat the weather variables measuring go to step 3, else go to step 9.
- 9- End.

6. Results and Discussion

The proposed system was calibrated through using advanced equipment meter type PROVA, which contains a thermometer and anemometer sensor.

The results which were obtained from the proposed system for five days were plotted in **Figs. 10** and **11** for temperature and wind speed measuring results and the wind direction results for five days are put it in table 2.

The measurements of the variables have been compared with the same variables value obtained from portable measurement equipment type PROVA (AVM-07) and the results which observed in **Figs. 12** and **13**. From this comparison show us very good level of stability as well as accuracy.

7. Conclusions

The focus of the paper is in using digital data acquisition system based on microcomputer for measuring a multi type of variable.

The following points are the most important outline which obtained from this paper.

1. The system usefulness is as a teaching tool that let engineers and scientific user to exercise their programming skills in order to

Acquire and store, process data and display the process in to engineering form.

2. Data acquisition system based on microcomputer is more efficient and economical than conventional system because it can be programmed at predetermined time.
3. The graphics capabilities of the microcomputer have been exploited so that several system variables can be observed simultaneously. Consequently, no additional recording instruments are required.(Hence the computer will store all the data on hard disk, and we don't need an external storage devices.
4. The general purpose nature of the microcomputer based system has been demonstrated and also we have been considered for illustrating basic important concept of data acquisition for real-time multi-variable measurement system.
5. Data acquisition system based on microcomputer provides the user with flexibility of selecting various variable type of process measurement. The system has the ability to deal with multi-variable at the same time.
6. The use of digital techniques for data acquisition system makes these systems more accurate, reliable, and simpler.

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Table 1 Input And Output Address Mapping.

Addresses	Function description
300 H	Address of analogue channel select
301 H	A/D enable and start conversion
302 H	Statue of A/D (EOC)
303 H	A/D data reading enable

Table. 2 Illustrated the results of wind direction for five days.

Time (hr)	Date				
	1/11/2010	7/11/2010	14/11/2010	21/11/2010	28/11/2010
Direction					
1	NE	N	WN	WN	NW
2	NE	N	NW	NW	WN
3	N	NW	NW	NW	NW
4	N	N	NW	WN	NW
5	N	W	NW	W	WN
6	N	W	W	W	WN
7	N	W	WN	WN	NW
8	NW	WN	WN	N	NW
9	NE	NW	NW	N	NW
10	N	NW	WN	NW	NW
11	NE	N	NW	WN	NW
12	NE	N	NW	WN	WN
13	N	NE	NW	WN	WN
14	NE	NE	WN	W	NW
15	NE	W	WN	W	NW
16	NE	N	WN	WN	WN
17	N	N	N	WN	WN
18	N	WN	N	N	W
19	NW	NW	NE	N	NW
20	NW	N	NE	NE	NW



21	NW	NE	N	E	WN
22	NW	NE	NW	NE	NW
23	NW	N	NW	N	W
24	NW	N	W	WN	W



Fig. 1 Illustrates Wind Direction Sensor.



Fig. 2 Illustrate Types Of Wind Speed Sensor.

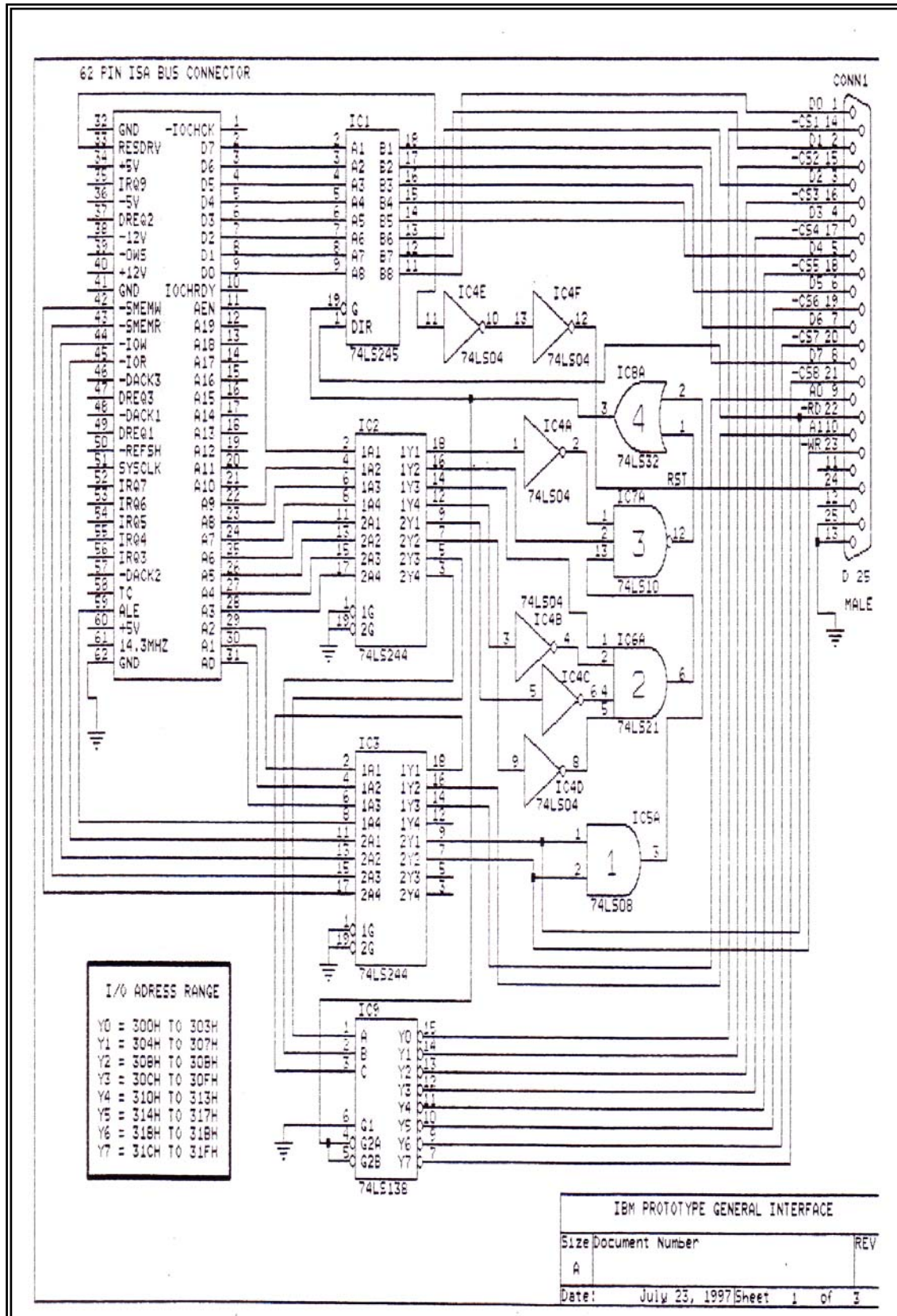


Fig. 3 Illustrate The Detail Of Digital Interfacing Circuit For ISA Bus.

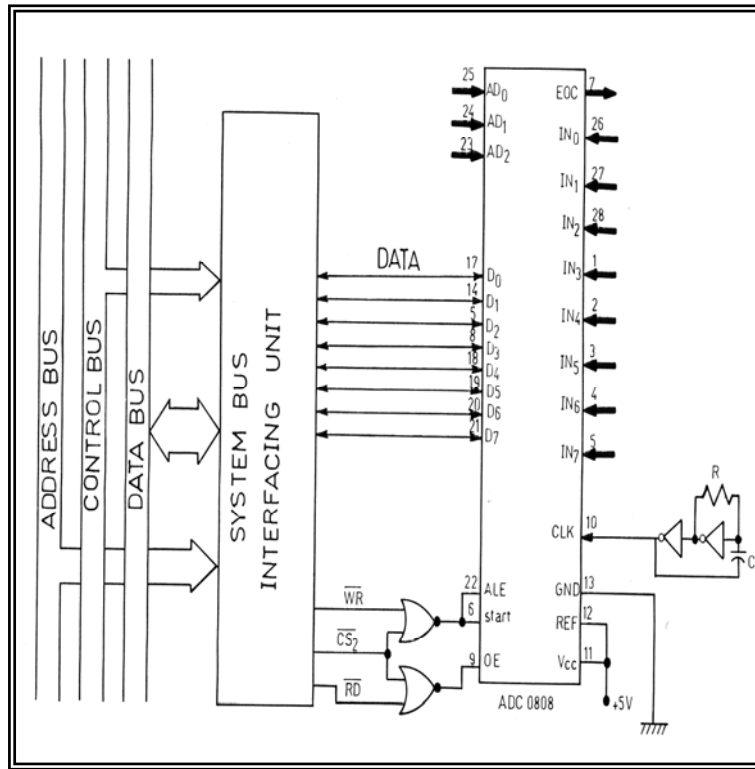


Fig. 4 Illustrates The Data Acquisition System.

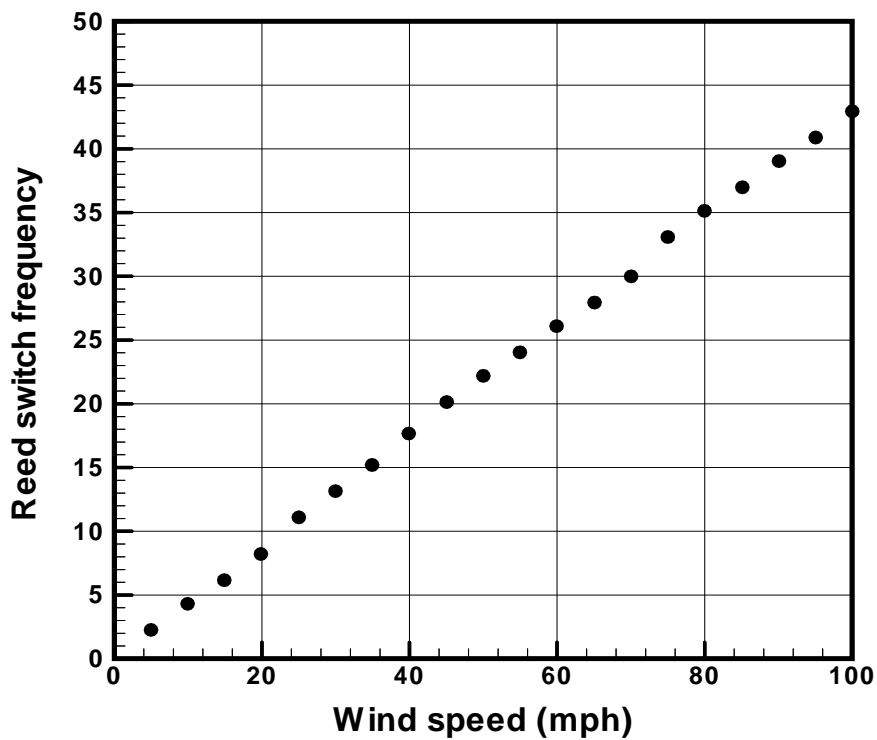


Fig. 5 Illustrate A Relations Ship Between The Reed Switch Frequency And Wind Speed.

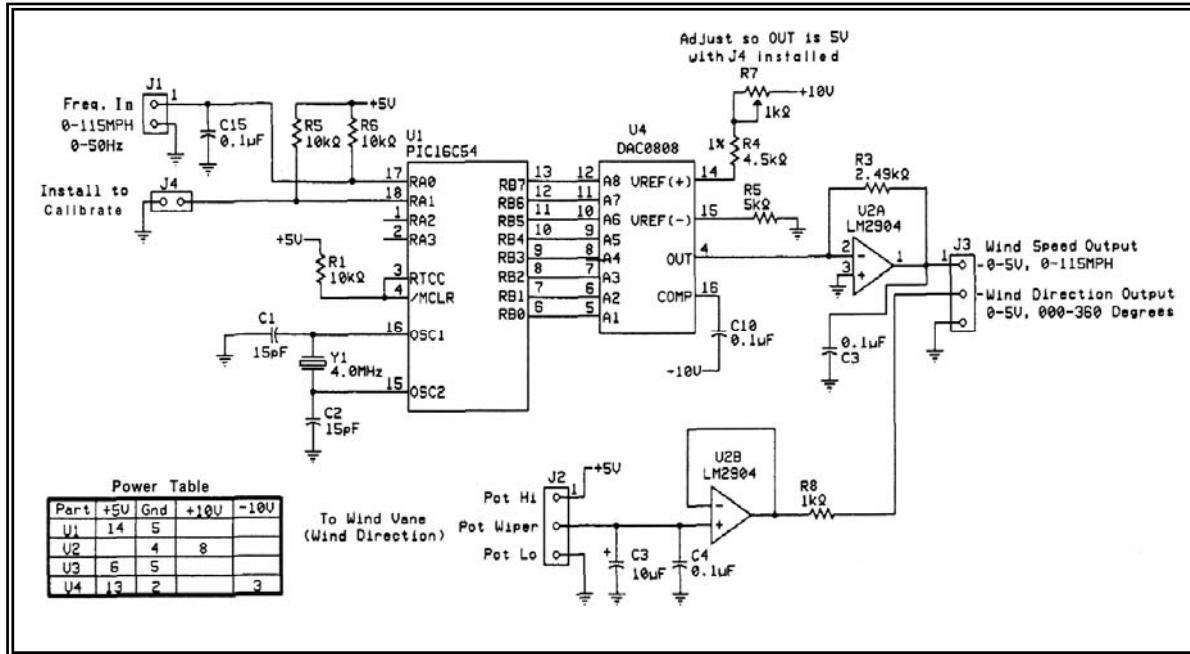


Fig. 6 Illustrate the Electronic Circuit Details Wind Speed and Direction Transducer.

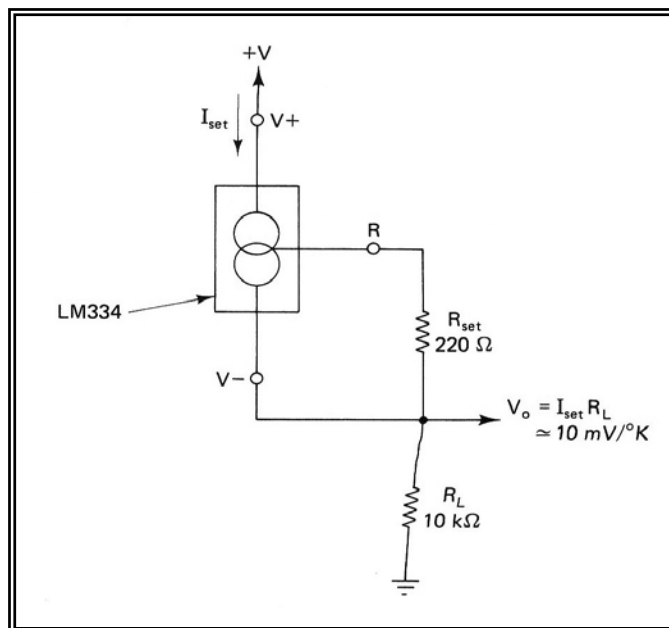


Fig. 7 Illustrate LM334 Connection Diagram.

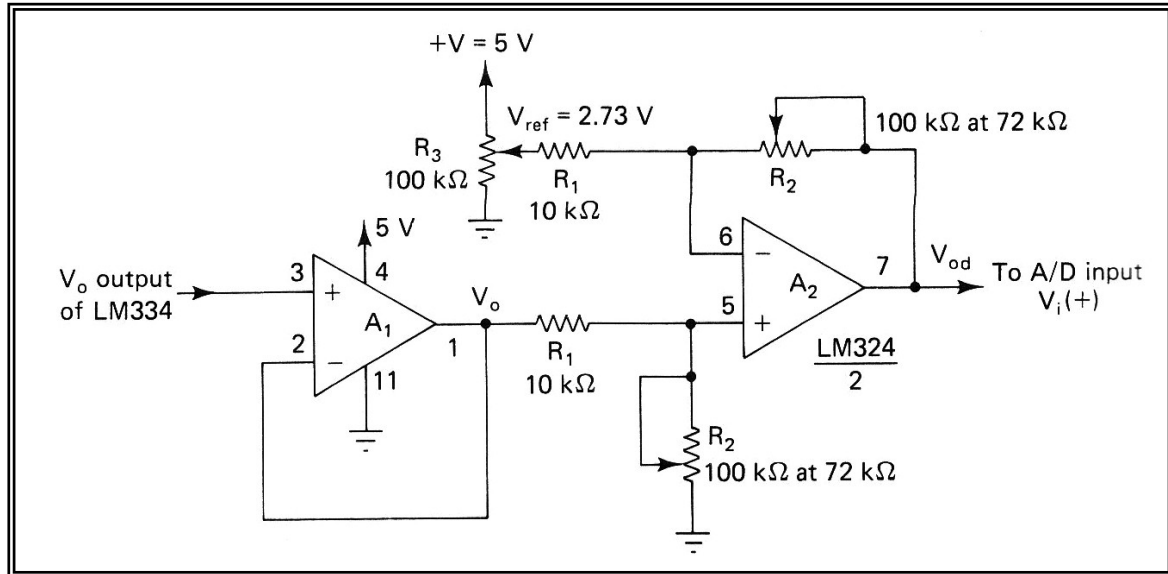


Fig. 8 Illustrate the Signal Conditioning Through Voltage Follower and Differential Amplifier.

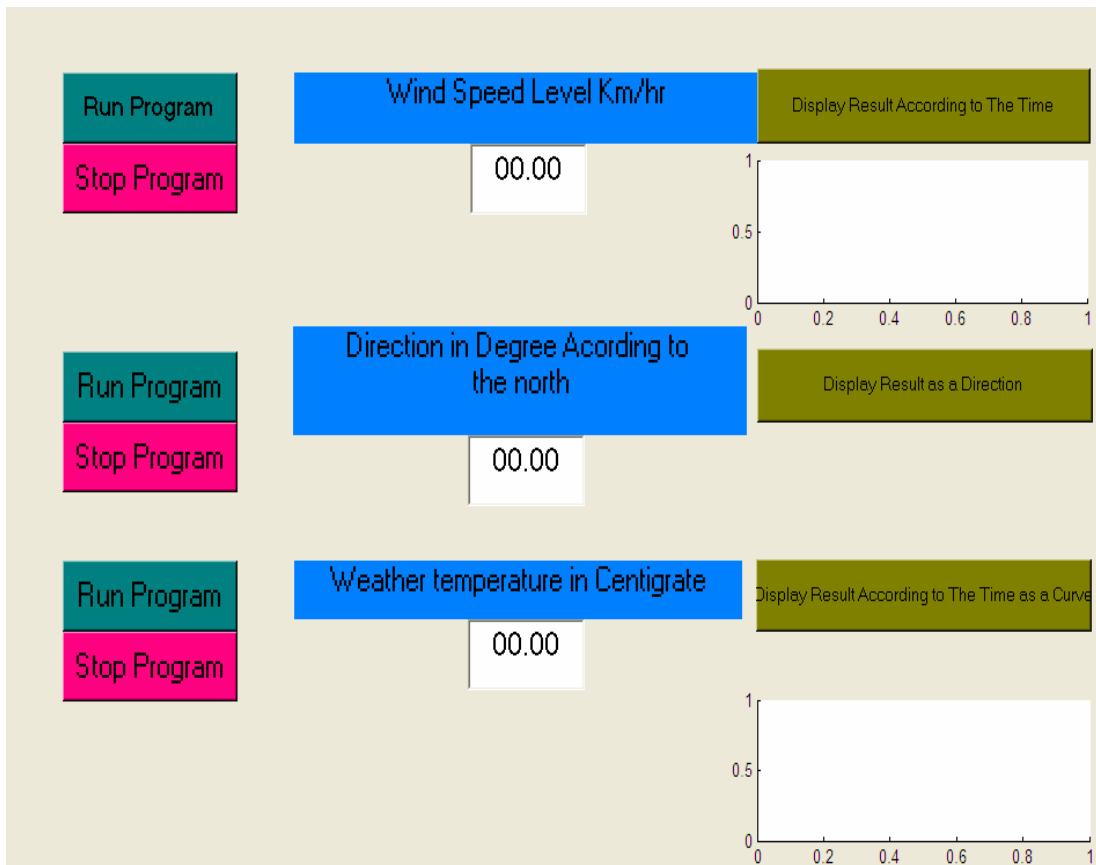


Fig. 9 Illustrate User Window (Man-Machine Interface) MMI.

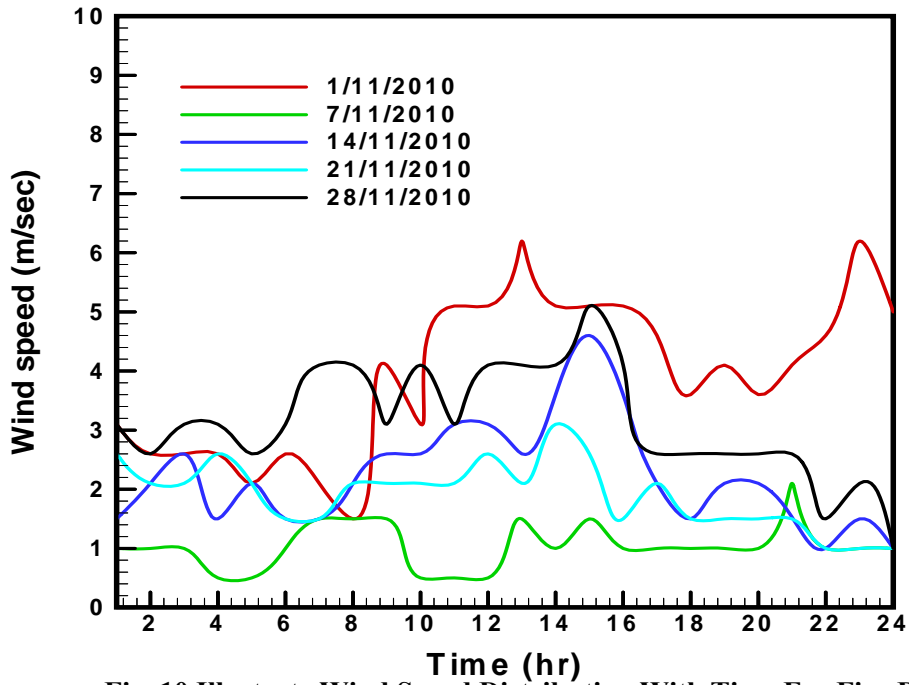


Fig. 10 Illustrate Wind Speed Distribution With Time For Five Days.

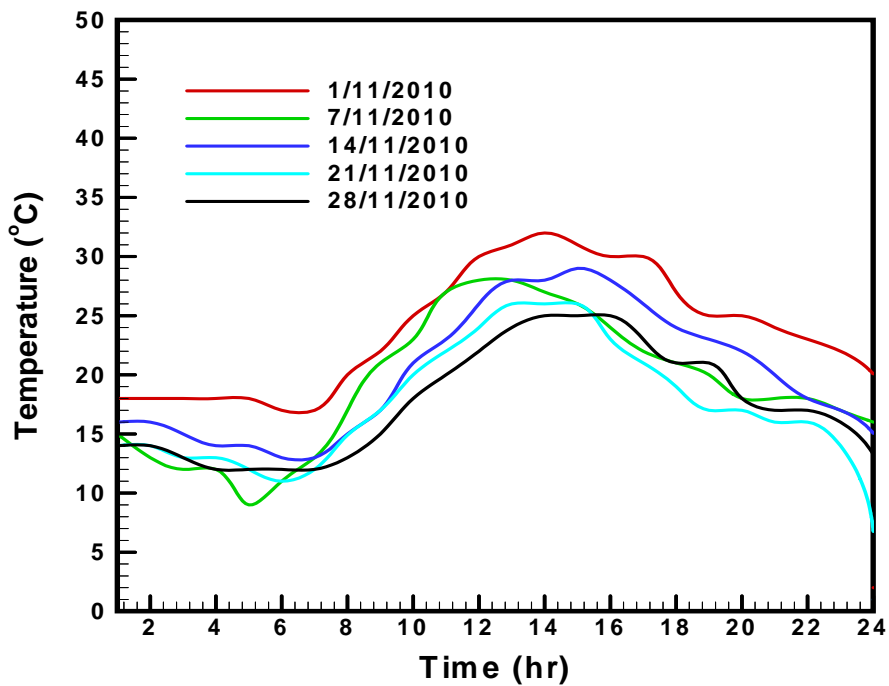


Fig. 11 Illustrate Temperature Distribution With Time For Five Days.

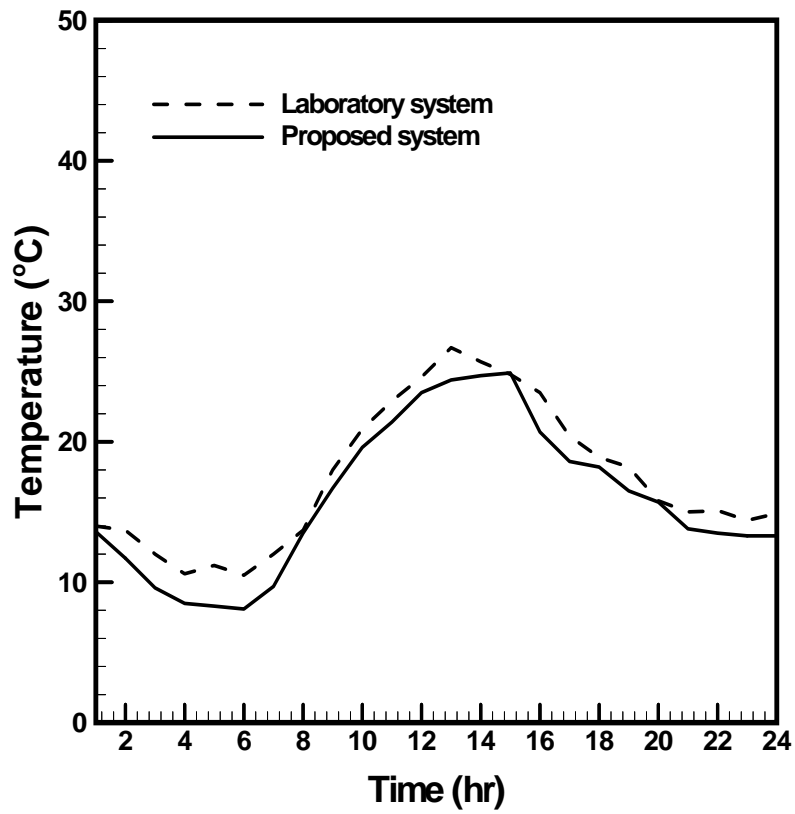


Fig.12 Illustrate The Comparison Of Temperature For Proposed System And Laboratory System.

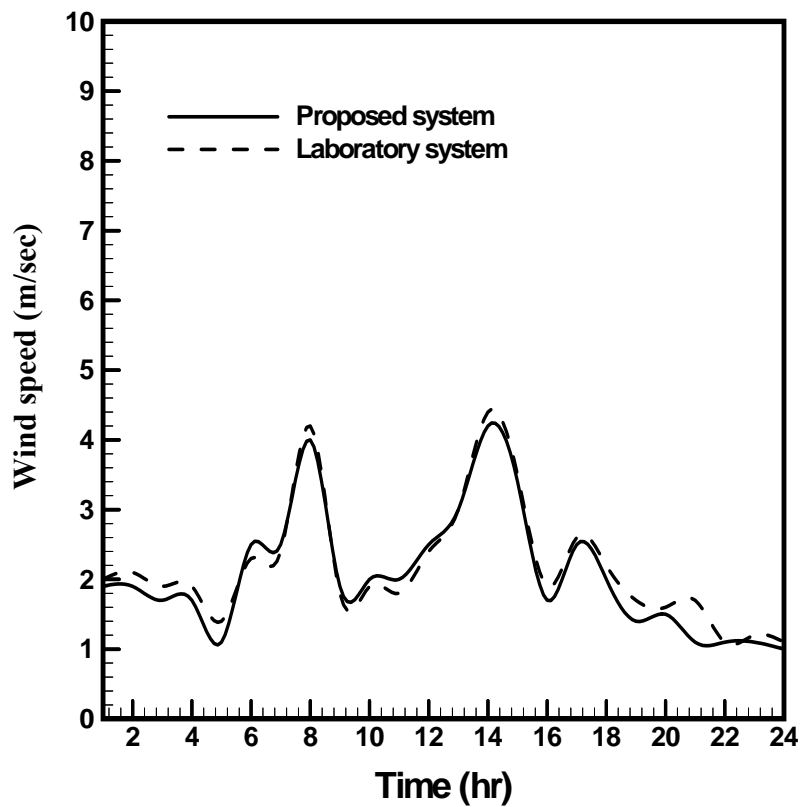


Fig.13 Illustrate The Comparison Of Wind Speed For Proposed System And Laboratory System.