A Low-Cost Microcontroller-based Weather Monitoring System

Kamarul Ariffin Noordin*, Chow Chee Onn and Mohamad Faizal Ismail

Department of Electrical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

**Corresponding author. E-mail: kamarul@um.edu.my*

ABSTRACT

The measurements of temperature, atmospheric pressure and relative humidity remotely by using the appropriate sensors is not only important in environmental or weather monitoring but also crucial for many industrial processes. A device for weather monitoring has been developed as described in this paper to monitor and display the temperature, pressure and relative humidity of the atmosphere, using analogue and digital components. The analogue outputs of the sensors are connected to a microcontroller through an ADC for digital signal conversion and data logging. An LCD display is also connected to the microcontroller to display the measurements. For analysis and archiving purposes, the data can be transferred to a PC with a graphical user interface program through a USB link. The interface program allows sampling parameters such as the date and time of the data-logging operation to be configured. The device has many advantages as compared to other weather monitoring systems in terms of its smaller size, huge memory capacities, on-device display, lower cost and greater portability.

Key words: Weather monitoring, Temperature, Relative humidity, Pressure, Sensors; Microcontroller

INTRODUCTION

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 temperature, humidity and pressure need to be measured (Ong et al., 2001), thus sensors have always been given 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 (ISO 7730, 1984; Bu et al., 1995). The advancement in technology has made these small and reliable electronic sensors capable of monitoring environmental parameters more favourably. Kang and Park (2000) and Odlyha et al., (2000) have developed monitoring systems, using sensors for indoor climate and environment based on the parameters mentioned.

Combination of these sensors with data acquisition system has proved to be a better approach for temperature and relative humidity monitoring (Moghavvemi et al., 2005). Ong et. al., (2001) and DeHennis and Wise (2005) introduced wireless sensing microsystem for environmental monitoring, using capacitive-based sensors. Vlassov et al., (1993) and Buff et al., (1994) introduced the usage of surface acoustic waves (SAW) devices as temperature sensor and pressure sensor respectively. These systems, however, are quite expensive and complex in nature as some of them require the use of on-chip transmitter circuit and involve fabrication processes.

This paper aims to build a low-cost, yet reliable, weather monitoring system capable of acquiring and recording data. The proposed system has three sensors that measure the temperature, relative humidity and pressure, respectively. The analogue outputs of the sensors will be converted to digital signals and further processed by a microcontroller, acting as data logger. The logged data can then be transferred to a PC having a graphical user interface program for further analysis or printing the measurements. Using easily-available components and simple circuitry, the system should be beneficial in providing a portable and low-cost remote weather monitoring system.

THE SYSTEM CIRCUIT

The system is divided into four main parts, namely, the sensor circuit, the data-logging circuit, the time-keeping circuit and the USB interfacing circuit. The sensor circuit contains the IC temperature sensor, resistive humidity sensor and barometric pressure sensor. The analogue outputs from these sensors are converted into digital signal by an ADC before being fed into the data-logging circuit which encompasses a microcontroller. The current time for data-logging purposes is provided by the time-keeping circuit while the USB interfacing circuit facilitates the data transfer between the data logger and a PC. The block diagram of the overall system is depicted in Figure 1.

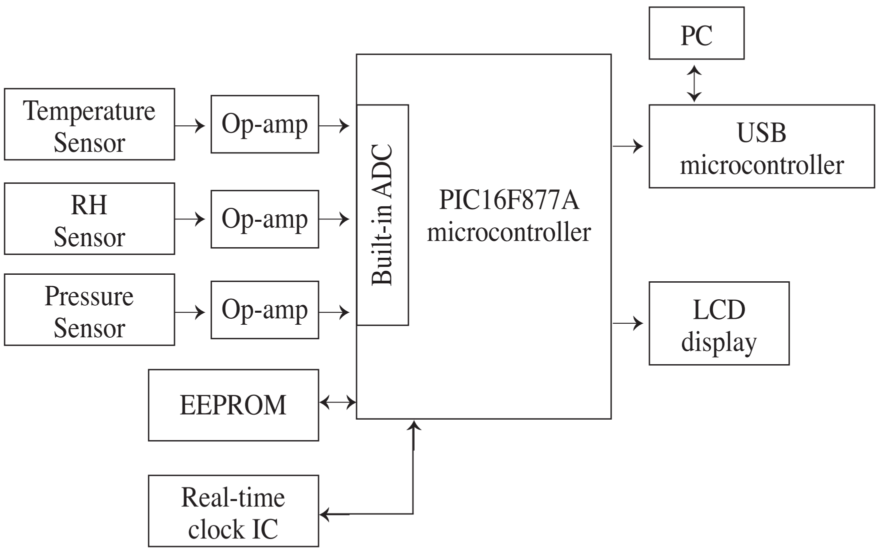

Figure 1. Block diagram of the system.

The Sensor Circuit

For temperature sensing, an integrated circuit temperature sensor LM35 is used. The output voltage of the sensor is linearly proportional to the temperature (in Kelvin or Celsius) with the gradient of 10mV/°C and able to operate in the range of -55°C to 150°C. As the device is to be used in the tropical climate area where the temperature never drops below 0°C, the temperature range for this system has been offset to the range of 0°C to 80°C, using an op-amp.

Relative humidity measurement is performed by the resistive-based humidity sensor, HSP15A from GE. The change in electrical impedance is inversely proportional to the relative humidity. This sensor can only be biased using AC voltage. Biasing with DC voltage can damage the sensor due to the electrolysis of the conductive polymer that causes polarization. Therefore, a pulse generator is used to drive the sensor, as shown in Figure 2, and the output of the sensor is rectified, using a rectifier circuit to obtain a DC voltage.

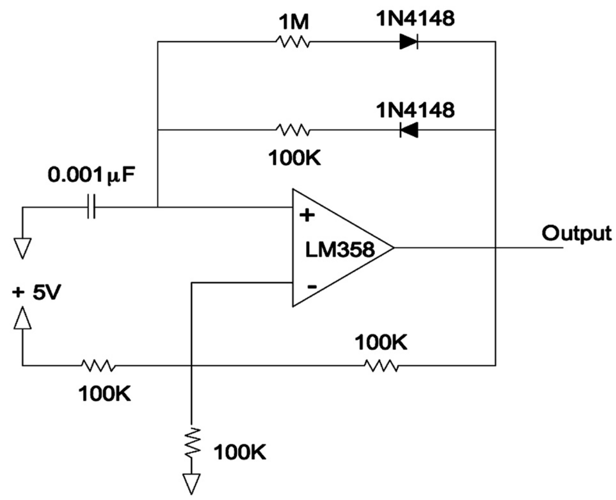

Figure 2. Pulse generator circuit.

For pressure measurement, the barometric pressure sensor, MPX4115A is employed. Its output voltage in the range of 0.2V to 4.8V is linearly translated into pressure measurement of 15kPa to 115kPa. This sensor is also temperature-compensated from -40°C to 125°C, thus suitable to be used with this system.

An ADC performs the conversion of all analogue outputs from the sensors into digital signals to be fed to the microcontroller. Amplification and offset adjustment (as in temperature sensor) of these signals are provided by the LM358 op-amp. Although amplification is necessary to suit the input range of the ADC, noise from sensors is also amplified. To alleviate this problem and to maintain consistency of the sensing system, a noise filtering circuit is added before the op-amp stage.

The Data-Logging Circuit

The main component here is the PIC16F877A microcontroller, which is equipped with 8 Kb of flash memory and 20 MHz of processing speed. This microcontroller not only controls the system but also synchronizes all the module operations. An EEPROM with 512 Kb capacity is connected to the microcontroller for storing the sensors' readings up to 60 days (for 30-second sampling interval). The interface of the EEPROM and the microcontroller is based on the I2C bus. The I2C bus provides a simple bi-directional 2- wire bus for efficient inter-IC control. An LCD module is also connected to the microcontroller to display the measurement of the sensors and the current time. The data logger also allows the user to browse through the recorded data and change the sampling interval.

The Time-Keeping Circuit

A real-time clock (RTC) chip is employed for time-keeping purpose. Communication between the chip and the microcontroller is achieved via a simple serial interface. The time will be displayed on the LCD. A separate battery source supplies the power required by the chip, hence enables its operation kept undisturbed in the event of main power source failure.

The Interfacing Circuit and the GUI

Data stored in the EEPROM can be accessed directly with a personal computer (PC) through USB connection. This connection is established via a USB interface microcontroller named 16C745, manufactured by Microchip.

The graphical user interface (GUI) software was developed, using Visual Basic. The software allows the user to download data from the EEPROM, completely or partially. It also enables the user to change the sampling parameters such as date, time and sampling interval. The data can also be plotted with the built-in graph plotter or exported to Excel for further analysis.

RESULTS AND DISCUSSION

The accuracy of the proposed system has been tested through extensive experiments. The measurements have been compared with those obtained, using more-advanced equipment used by the Malaysian Meteorological Services Department (MMS), which contains a thermometer, a relative humidity sensor with chart recorder and PTB220A1 pressure transmitter from Vaisala for temperature, relative humidity and pressure measurements respectively. The results obtained are summarized in Table 1, Table 2 and Table 3.

Table 1. Comparison of temperature measurements.

Lab thermometer (°C)	Proposed system (°C)	Difference (°C)
29.5	29.7	- 0.2
29.8	29.6	0.2
29.9	29.1	0.8
29.9	29.3	0.6
30.1	29.6	0.5
30.2	29.5	0.7
30.2	29.2	1.0
30.8	29.7	1.1
30.8	29.8	1.0
30.8	30.0	0.8

Table 2. Comparison of relative humidity measurements.

Lab RH sensor (%RH)	Proposed system (%RH)	Difference (%RH)
65	63	2
65	66	-1
64	66	-2
64	67	-3
63	65	-2
61	59	2
61	59	2
61	59	2
60	58	2
58	57	1

Table 3. Comparison of pressure measurements.

Pressure Transmitter (kPa)	Proposed system (kPa)	Difference (kPa)
100.54	100.7	-0.16
100.54	100.7	-0.16
100.54	100.7	-0.16
100.54	100.8	-0.26
100.54	100.9	-0.36
100.54	100.8	-0.26
100.53	100.8	-0.27
100.53	100.7	-0.17
100.53	100.9	-0.37
100.53	100.8	-0.27

From Table 1, it can be observed that the temperature sensor shows a good level of stability as well as accuracy. The average error of 0.7°C is observed due to ±0.5°C error by the sensor and ±0.25°C introduced by the ADC. Although the direct interface between the sensor and the microcontroller could affect the accuracy of the measurement, the relative error is quite small, as suggested by Reverter et al., (2005). Meanwhile, the humidity sensor of the proposed system also shows a very good accuracy as shown in Table 2. An average error of 2% is observed mainly due to the hysteresis effects of the sensor. The pressure sensor produced the most accurate measurements compared to other sensors with an average error of ±0.2 kPa as shown in Table 3.

Several portable weather station devices available in the market are compared with the proposed system in terms of features and accuracy. The comparisons are listed in Table 4. It can be seen from Table 4 that the proposed system has a much larger memory capacity for data-logging purpose compared to other weather station devices in which one of them needs a separate data logger. Apart from having a graphical user interface for configuring the sampling time and acquiring data from the data logger for analysis purposes, the system also offers the range and accuracy comparable to industrial-grade equipment. The cost of the system which is significantly lower compared to other systems with similar features is another advantage of this system.

Table 4. Comparisons of other weather station devices with the proposed system.

	JDC Instruments SKYWATCH	Kestrel 4000 Pocket Weather Tracker	Grant Mini-met Weather Station	Oregon Scientific WM-918	Proposed system
Temperature Accuracy	±0.5°C	±1°C	±0.4°C	±2°C	±0.7°C
RH Accuracy	±3%	±3%	±2%	±6%	±2%
Pressure Accuracy	±0.2 kPa	±0.3 kPa	±0.03 kPa	±0.7 kPa	±0.2 kPa
Memory Capacity	-	250 measurements	64000 measurements (separate data logger)	-	512 Kb
Backup power	CR2032 lithium battery batteries	2 AAA alkaline batteries	12 V rechargeable battery and solar power supply	8 AAA batteries	Rechargeable 9V battery
Price (US$)	380	330	Not available	90	< 70

CONCLUSION

A framework has been presented that incorporates the uses of sensors in developing a low-cost, high-accuracy weather monitoring system, using analogue and digital components. The proposed system has been tested through extensive experiments and the results have proven the accuracy and reliability of the proposed system. Besides, a comparison on the features of different types of monitoring systems has been carried out and it shows that the proposed system is of better choice in terms of cost, portability, memory capacity and logging interval-setting capability.

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