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ARM Processor Based Multisensor System Design for the Measurement of Environmental Parameters

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Abstract: This paper presents the design and development of an embedded system for the measurement of environmental parameters such as temperature, relative humidity, atmospheric pressure and the gas pollutants like CO, CO_2, NH_3, SO_2, and NO_2 present in air. The system is developed around an advanced ARM processor (LPC2378) by interfacing the relevant sensors. The data sensed by the sensors is displayed on a 2 × 16 LCD and also sent to a PC by using a wireless module. A graphical user interface is developed using the Visual basic software for the analysis of data. The results are discussed in detail. *Copyright © 2012 IFSA.*

Keywords: ARM processor, Temperature sensor, Humidity sensor, Gas sensors, IAR workbench, Visual Basic.

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1. Introduction

The unprecedented growth in modern technologies and the continued development of industrialization has made the issue of environmental pollution increasingly serious and alarming. This environmental pollution can be classified in to three categories: atmospheric pollution, soil pollution and water pollution. So the environmental monitoring is the essential step to resolve this problem. The purpose of the environmental monitoring is to reflect the quality of the environment statuesque and its development trend accurately, timely and comprehensively for providing the scientific basis for the environmental management, pollution control and environmental planning, etc [1]. The measurement of temperature, humidity, atmospheric pressure and wind velocity etc. is important not only in environmental or weather monitoring but also crucial for many industrial processes.

Another equally alarming situation in recent times is the increase in the concentration of gas pollutants like CO, CO_2, SO_2, NO_2 & NH_3 in the atmosphere. This is due to the domestic, vehicular traffic and industries which constantly emit these gas pollutants in to the atmosphere. The atmospheric pollution poses three severe effects such as global warming, ozone-layer depletion and air pollution. Among these three, global warming is the most critical in terms of environmental conservation and can cause serious damage to the human lives. So, the need for monitoring and controlling environmental parameters has become a very important task.

In view of this, many researchers tried to develop data loggers [2-4]. Earlier development of data logger was done through manual measurements using analog instruments such as thermometers and manometers. Unfortunately, this type of data logger systems can not fulfill the current needs in terms of time and accuracy. From 1990, a further development in data logging took place as people began to create PC based data logging systems. As PC based loggers are found to be more expensive and complex, the designers started showing interest in single chip based systems i.e., the microcontroller based data logging systems. The use of microcontrollers in embedded design is not only increased but brought revolutionary changes in the entire field of embedded design. Monitoring and controlling environmental parameters by embedded systems using microcontrollers is very much effective in meteorological and industrial requirements. Due to the ever increasing need for such measurement and monitoring of these parameters, many workers tried to design suitable data logging systems using different microcontrollers [5-7]. Today a number of microcontrollers are available in the market from different vendors. Each device has its own advantages and limitations.

With the growing importance of the embedded systems, the need to design embedded applications with microcontrollers having advanced features is gaining prominence. Few years back most of these systems designed based on PIC microcontrollers. But in recent times designers are inclining towards the ARM processors due to the availability of tremendous features which are more suitable for embedded system design, especially low-power designs. ARM is the leader in microprocessor Intellectual Property. ARM designs and licenses fast, low-cost, power-efficient RISC processors, peripherals and "system-chip" solutions for embedded control, consumer/educational multimedia, DSP and portable applications. ARM supports its processor offerings with Development Hardware and Software and contract Design Services. ARM is emerging as the de facto standard for embedded RISC processing across communication, networking, consumer, portable, automotive and multimedia application markets. ARM offers an array of cores, architectural extensions, microprocessors and system-on-chip (SoC) solutions, all using common software architecture.

2. Hardware Details

The hardware details are shown in the Fig. 1. Here the various sensors used in the present design are interfaced to the ARM core using the necessary signal conditioning circuits. The specifications of the sensors used in the present work are shown in Table 1.

The details of various blocks of the embedded system developed in the present work are explained below. In the present work the sensors available locally at a very low cost are chosen. All these sensors have the output either as current or voltage. Suitable signal conditioning circuits are designed. In fact for more efficient and improved performance one can use the universal integrated frequency to digital converter (UFDC) developed by Yurish et. al [8]. Additionally the use of the UFDC ICs will also make the design simpler. But, unfortunately, the authors failed to use these ICs as they are not available locally and also a tedious task for such a low budget project. Any how, as we have mentioned at the end of this paper, we are developing a more sophisticated wireless sensor system for metrological applications, for which we are planning to procure the frequency output sensors and the UFDC ICs, which make the design simpler.

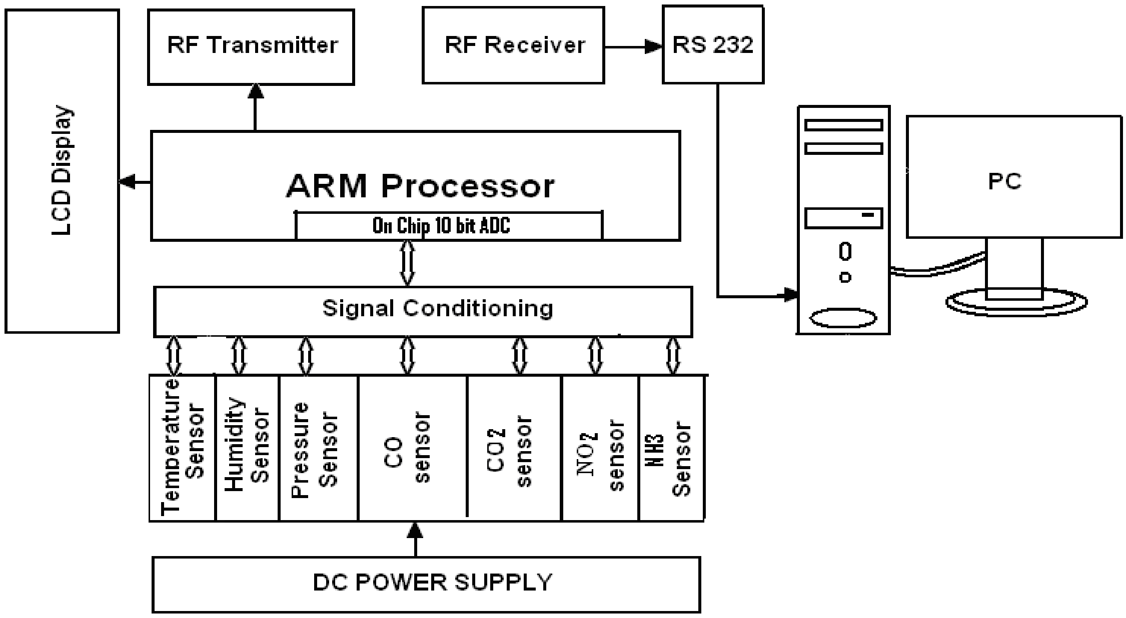

Fig. 1. The block diagram of the embedded design.

Table 1. Specifications of Sensors used in the present work.

S. No	Name of the sensor	Manufacturer	Operational Range	Sensitivity
1.	LM35 Temperature sensor	National Semiconductor, USA	-40 to110^0 C	10 mV/^{o}C
2.	Humidity Sensor SY-HS-220	SY HITECH (China)	30~90 % RH	DC 1,980 mV (at25oC 60RH
3.	Pressure Sensor NPC1220	GE Sensing	0 psi to 5 psi	50 mV
4.	CO Sensor MQ7	Henan Hanwei Electronics Co., Ltd. China	10 to 10,000 ppm	~ 50 mA
5.	CO_2 Sensor MG811	Henan Hanwei Electronics Co., Ltd., China	0-10,000 ppm	3050 mV
6.	NO_2 Sensor	Alphasense, UK	0 to 20 ppm	-400 to -750 nA/ppm
7.	SO_2 Sensor	Alphasense, UK	0 to 100 ppm	300 to 440 nA/ppm
8.	NH_3 Sensor MQ135	Henan Hanwei Electronics Co., Ltd., China.	10 -300 ppm	~25 nA/ppm

2.1. ARM Processor

The LPC2378 (Philips) ARM processor is based on a 16-bit/32-bit ARM7TDMI-S CPU with real-time emulation that combines the Microcontroller with 512 kB of embedded high-speed Flash memory. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at the maximum clock rate. The LPC2378 is ideal for multi-purpose serial communication applications. It incorporates a 10/100 Ethernet Media Access Controller (MAC), USB full speed device with 4 kB of end point RAM, four UARTs two CAN channels, an SPI Interface two Synchronous Serial Ports (SSP), three I^2C Interfaces an I^2S Interface and an External Memory controller (EMC). This blend of serial Communications Interfaces combined with an on-chip 4 MHz internal oscillator SRAM of 32 kB, 16 kB SRAM for Ethernet, 8 kB SRAM for USB and general purpose use, together with 2 kB battery powered SRAM make this device very well suited for communication gateways and protocol converters. Various 32-bit timers an improved 10-bit ADC, 10-bit DAC PWM unit, a CAN control unit, and up to 104 fast GPIO lines with up to 50 edges and up to four level sensitive external interrupt pins make these Microcontrollers particularly suitable for Industrial Control and medical systems. A very important feature of this processor is its low power consumption which made it a most sought-after device for scientific and industrial designs [9].

2.2. Temperature Measurement

Measurement and monitoring of temperature is always a vital task in environmental studies. Also it is essential in all industrial and chemical processes. Temperature is measured using temperature sensors. Four technologies are currently in use: thermocouples, thermistors, resistance temperature detectors, and integrated circuit (IC) sensors. Most temperature sensors produce an analog output voltage which is proportional to the temperature. Analog sensors require analog-to-digital (A/D) converters, so that the output voltage can be converted into digital form, suitable for interfacing to a microcontroller. Temperature is sensed using a LM35 type analog sensor. LM35 is a simple but accurate 3-pin temperature sensor IC. Pin 1 of the device is connected to the power supply (+5 V), pin 3 is connected to the ground. Pin 2 is the output and this output provides a voltage which is directly proportional to the ambient temperature. The device can measure temperature from 2 ºC up to 100 ºC (some types can measure a wider range) and the output voltage to temperature relationship is 10 mV/ºC. [10]. For example, at 20 ºC the output voltage is 200 mV. The output of the temperature sensor IC is connected to the on chip ADC of the ARM microcontroller.

2.3. Measurement of Humidity

The measurement of Humidity in the atmosphere has many domestic as well as industrial applications. But the accurate measurement of humidity is always a difficult task as it is affected by other factors like atmospheric pressure and temperature etc. So, the compensation of temperature is very important. The capacitive sensors are in wide use due to their special features like fast response, superior linearity, sensitivity and stability [10-11].

Keeping in view the SY-HS-220 series Humidity sensor is used in the present work. This module converts relative humidity to output voltage [12]. Its operating voltage is 5 V DC and its operating temperature is 0 - 60˚ C and its operating humidity is 30- 90 % RH. Its standard out put at 25 ˚C and 60 % RH is 1980 mV DC. The linear behavior of this sensor is shown in Fig. 2.

2.4. Measurement of Pressure

The measurement of the atmospheric pressure is done using the NPC-1220 series solid state pressure sensor. This sensor is based on piezo-resistive sensitive technology. [13]. the output of this pressure sensor is in millivolts. The NPC-1220 offers the added advantage of superior temperature performance over the temperature compensated range of 0°C to +60°C and the NPC-1220 series is available in pressure ranges from 0 to 5 through 0 to 100 psi. The signal conditioning of the pressure sensor is shown in the Fig. 3.

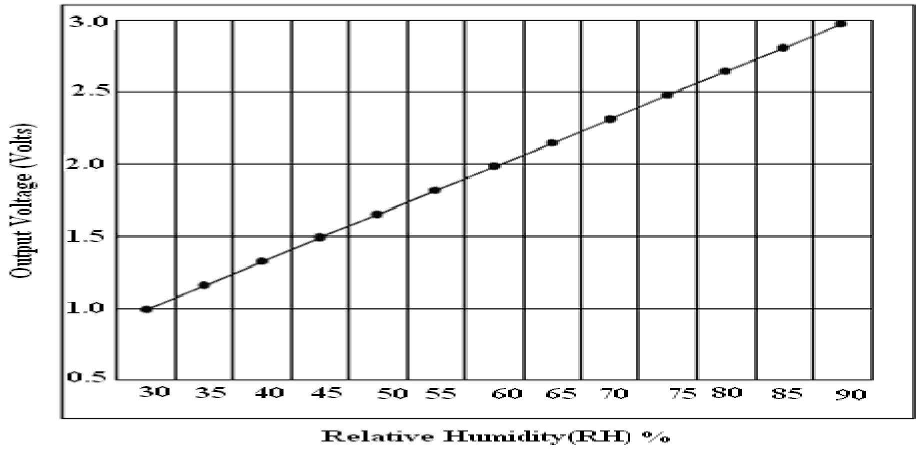

Fig. 2. The linear behavior of Humidity sensor.

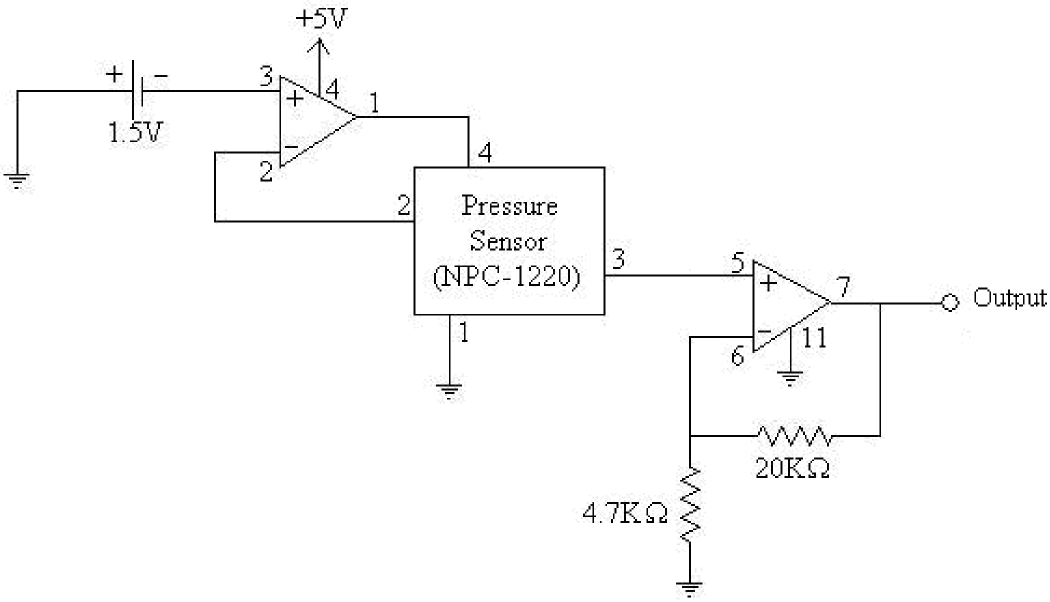

Fig. 3. Signal conditioning Circuit for Pressure sensor.

The circuit consists of LM324 operational amplifiers, which are high gain, internally frequency compensated amplifiers designed specifically to operate from a single power supply over a wide voltage range. The analog output voltage of the sensor is given to ARM controller. The pressure sensor generates 0 to 50 mV of output voltage for a 0- to 15-psi pressure range.

2.5. Measurement of CO

Measurement of gas pollutants in atmosphere is always a challenging job due to the accuracy required in its measurement. Among the various gas sensors available in the market semiconductor sensors are considered to have fast response, high stability, low cost, long life, low dependency on humidity, low power consumption, and compact size etc. The semiconductor sensor consists of one or more metal oxides such as tin oxide, aluminum oxide etc. When heated to a high temperature an N-type semiconducting material decreases its resistance while P-type increases its resistance in the presence of a reducing gas. So, a semiconductor sensor produces a strong signal at high gas concentrations. The basic disadvantage of a gas sensor is its poor selectivity [14-16].

Carbon monoxide, produced by burning petroleum in automobiles, as well as by the combustion of wood, coal, and other carbon-containing fuels, is extremely hazardous to human health. It bonds with iron in hemoglobin, the substance in red blood cells that transports oxygen throughout the body, and in effect fools the body into thinking that it is receiving oxygenated hemoglobin, or oxyhemoglobin. Upon reaching the cells, carbon monoxide has much less tendency than oxygen to break down, and therefore it continues to circulate throughout the body. Low concentrations can cause nausea, vomiting, and other effects, while prolonged exposure to high concentrations can result in death. Carbon monoxide is also known as silent killer [17].

In the present work to detect the carbon monoxide gas molecules present in the atmosphere MQ-7 sensor is employed. This sensor consists of micro Al_2O_3 ceramic tube, Tin Dioxide (SnO_2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. This Carbon Monoxide (CO) gas sensor detects the concentrations of CO in the air, and outputs its reading as an analog voltage. The sensor can measure concentrations of 10 to 10,000 ppm. The MQ-7 sensor has 6 pins, 4 of them are used to fetch signals, and other 2 are used for providing heating current [18].

The operating circuit is shown in Fig. 4. When its internal heating element is activated at 1.4 V the MQ-7 gas sensor responds to CO gas by reducing its resistance in proportion to the amount of CO present in the air exposed to the internal element

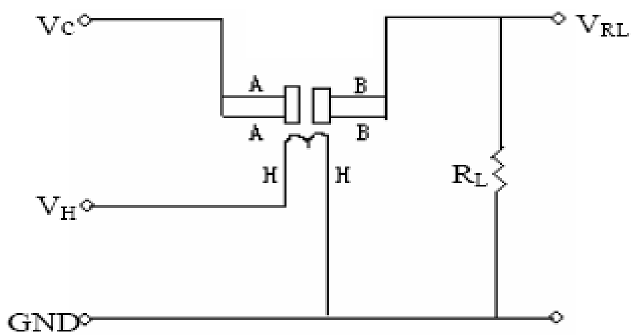

Fig. 4. Test circuit for CO sensor.

The correlation between the sensor resistance and the concentration of the CO gas in ppm (C) is expressed by the following equation [19]:

$$R_S = R_0 (1+K\sqrt{C}), \quad (1)$$

where Rs is the electrical resistance of the sensor;
R_0 is the electrical resistance of the sensor at zero ppm;
K is the constant for the particular sensor;
C is the gas concentration in ppm.

In the presence of reducing gas, due to the decrease in the height of the potential barrier, the resistivity of the sensor decreases logarithmically as shown below Fig. 5.

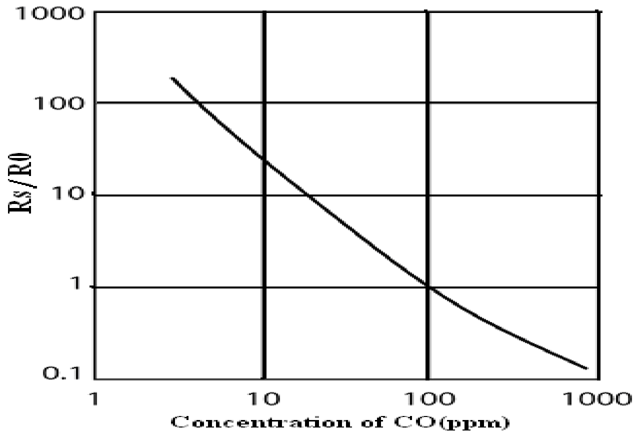

Fig. 5. Variation of Sensor resistance with CO concentration.

2.6. Measurement of CO_2

Carbon dioxide is a greenhouse effect gas, but at the same time it is associated with respiration of bio organisms and the photosynthesis of plants. Thus CO_2 sensors are important not only for monitoring the CO_2 levels in the atmospheric environments but also for measuring or controlling bio-activities. Carbon dioxide is generated as a byproduct of the combustion process of fossil fuels. Carbon dioxide content in fresh air varies between 300 ppm and 600 ppm, depending on the location. It is dangerous when inhaled in high concentrations (50,000 ppm). Carbon dioxide ppm levels are a surrogate for measuring indoor pollutants that may cause occupants to grow drowsy, get headaches, or function at lower activity levels [20].

In the present work MG 811 CO_2 Sensor is used to detect the CO_2 present in the atmosphere. This sensor features good sensitivity and selectivity to CO_2.It has low humidity and temperature dependency and long stability and reproducibility. When the internal heating element is activated, this gas sensor responds to CO_2 gas by generating a small voltage in proportion to the amount of CO_2 gas present in the air exposed to the internal element. The sensor is a high impedance device and requires a buffer/amplifier to measure the output. The calibration circuit is shown in Fig. 6 and it is employed as described in the data sheet [21].

The CO_2 sensor adopts solid electrolyte cell principle. When the sensor is exposed to CO_2 gas the following anodic and cathodic reactions takes place [22].

Cathodic reaction is

$$2Li^{+} + CO_2 + \frac{1}{2} O_2 + 2e = Li_2CO_3 \quad (2)$$

Anodic reaction is

$$2Na^{+} + \frac{1}{2} O_2 + 2e = Na_2O \quad (3)$$

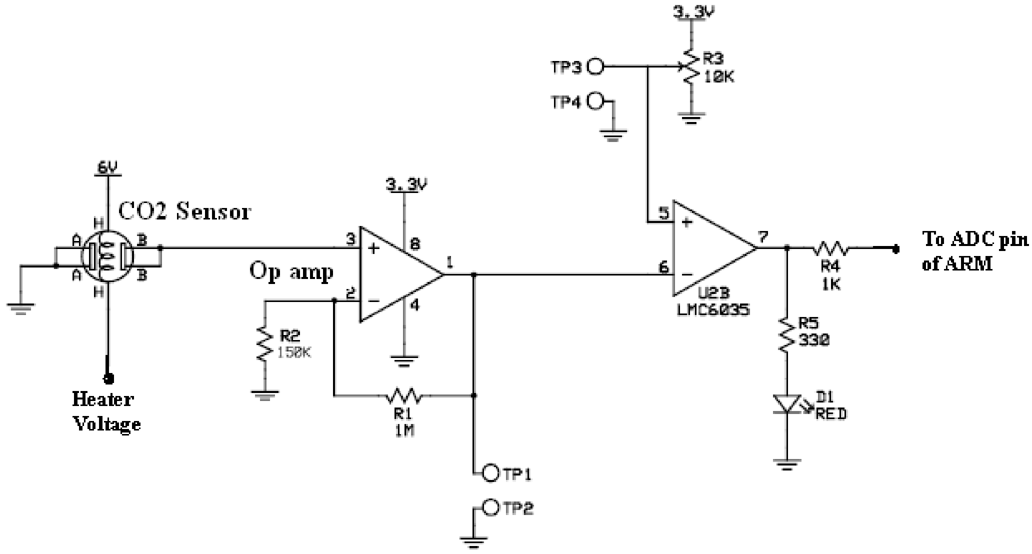

Fig. 6. Calibration circuit of CO_2 Sensor.

The overall chemical reaction is

$$Li_2CO_3 + 2Na^+ = Na_2O + 2Li^+ + CO_2 . \quad (4)$$

So, the EMF is developed when this sensor is exposed to the reducing gas. The developed voltage is in accordance with the concentration of the gas present in the medium. The relation between the output voltage and gas concentration in ppm is given by

$$C = \left[\left(\frac{(V_C R_L / V_O) - R_L}{R_0} - 1\right)\frac{1}{K}\right]^2 , \quad (5)$$

here V_C is the input voltage;
V_0 is the output voltage;
R_L is the load resistance;
R_S is the sensor resistance normally between 5 k Ω -15kΩ.

2.7. Measurement of NH_3

Ammonia is a colorless and poisonous gas with a pungent smell and fairly low odour threshold. Therefore, the monitoring and detection of NH_3 are of interest in many technological fields such as industrial processes, clinical diagnosis, and environmental monitoring. Ammonia is commonly used in many industries, including petrochemical, pulp and paper, fertilizer and the oil industry. Anhydrous ammonia (NH_3) is also very widely used as a coolant in large industrial refrigeration systems. The most widely recognized exposure limits for ammonia are an eight-hour TWA (Time Weighted Average) of 25 ppm, with a 15-minute STEL (Short Term Exposure Limit) of 35 ppm. Ammonia is also corrosive to the skin, eyes, and lungs. Exposure to 300 ppm is immediately dangerous to life and health. Fortunately, ammonia has a low odour threshold (20 ppm) with good warning properties, so most people seek relief at much lower concentrations. Besides its toxic properties, ammonia is also an explosively flammable gas, with a lower explosive limit (LEL) concentration of approximately 15 % volume. Although ammonia vapour is not flammable at concentrations of less than 15 %, it can easily explode or catch fire throughout its flammability range of 15 % to 28 % [23].

In the present work Ammonia sensor MQ135 is employed. The sensitive material of MQ135 sensor is SnO_2, which has lower conductivity in clean air. When the target combustible gas exist, the sensor's conductivity increases drastically as the gas concentration rising. MQ135 gas sensor has high sensitivity to Ammonia. The NH_3 sensor is composed of Al_2O_3 ceramic tube, Tin Dioxide (SnO_2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-135 has 6 pins, 4 of them are used to fetch signals, and other 2 are used for providing heating current as shown in the Fig. 4.The operating circuit is same as that of CO sensor shown in Fig. 4 [24].

2.8. Measurement of NO_2 and SO_2

Sulfur dioxide SO_2 and Nitrogen dioxide NO_2 are the important air pollutants. While the SO_2 is the primary air pollutant the NO_2 is both a primary and secondary air pollutant. Sulfur dioxide is a colorless gas with a pungent, suffocating odor. It is a dangerous air pollutant because it is corrosive to organic materials and it irritates the eyes, nose and lungs. Nitrogen dioxide (NO_2) is a gas of reddish-brown color with a distinct sharp, biting odor. Both these pollutants are dangerous to the human lives.

In the present work sensors from Alphasense (UK) SO_2 -BF and NO_2 –A1 are used. The operating circuit given in the data sheet [25] is directly implemented and the output of the sensors is fed to the ADC terminals of the ARM processor. To avoid the redundancy the circuits are not shown here.

2.9. Interfacing of LCD Module

In the present work a HD44780 a 2 × 16 Hitachi LCD module is used to display the measured data. It is based on the HD44780 microcontroller (Hitachi) and can display messages in two lines with 16 characters each. It displays all letters of alphabet, Greek letters, punctuation marks, mathematical symbols etc. In addition, it is possible to display symbols made up by the user. Other useful features include automatic message shift (left and right), cursor appearance, LED backlight etc Display contrast depends on power supply voltage and whether messages are displayed in one or two lines. For that reason, varying voltage 0-V_{dd} is applied on the pin marked as V_{ee}. Trimmer potentiometer is usually used for that purpose. Some LCD displays have built in backlight (blue or green diodes). When used during operation, a current limiting resistor should be serially connected to one of the pins for backlight (similar to LED diodes). If there are no characters displayed or if all of them are dimmed upon the display is switched on, the first thing that should be done is to check the potentiometer for contrast adjustment.

2.10. RF Transmitter Receiver Module

This module consists of both receiver and transmitter sections which work at 433.92 MHz. This allows the transmission of data between microcontroller and the PC in a wireless mode. The TWS-434 transmitter accepts both linear and digital inputs, and can operate from 1.5 to 12 Volts-DC. The transmitter output is up to 8 mW at 433.92 MHz with a range of approximately 400 feet in outdoors. In indoors, the range is approximately 200 feet.

The radio frequency (RF) receiver module is used to receive the data. The receiver also operates at 433.92 MHz, and has a sensitivity of 3 μV. The RWS-434 receiver operates from 4.5 to 5.5 volts-DC, and has both linear and digital outputs. RF receiver module RWS-434 is a highly sensitive passive design that is easy to implement. For maximum range, antenna should be approximately 35 cm long. The RF receiver is connected to the PC using the MAX 232 IC, which takes care of TTL signal problems. The transmitter and receiver blocks of the wireless modules are shown in Fig. 7. The data from the RF receiver is fed to the PC via RS232 cable when suitable baud rate and other features are selected [26]. The necessary interface diagram is shown in Fig. 8.

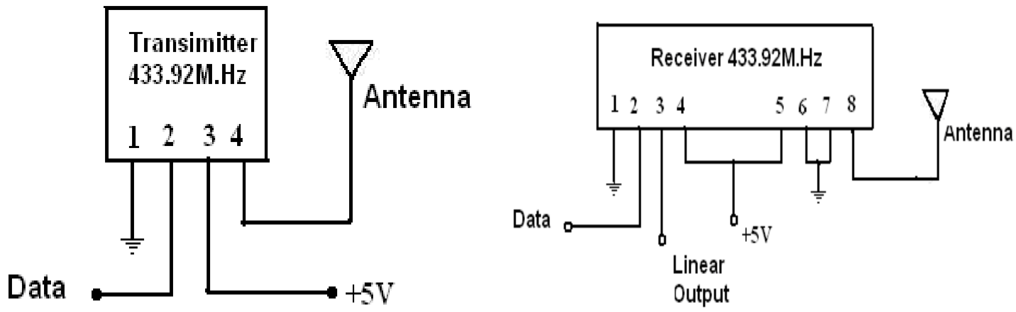

Fig. 7. Transmitter and Receiver blocks of Wireless module.

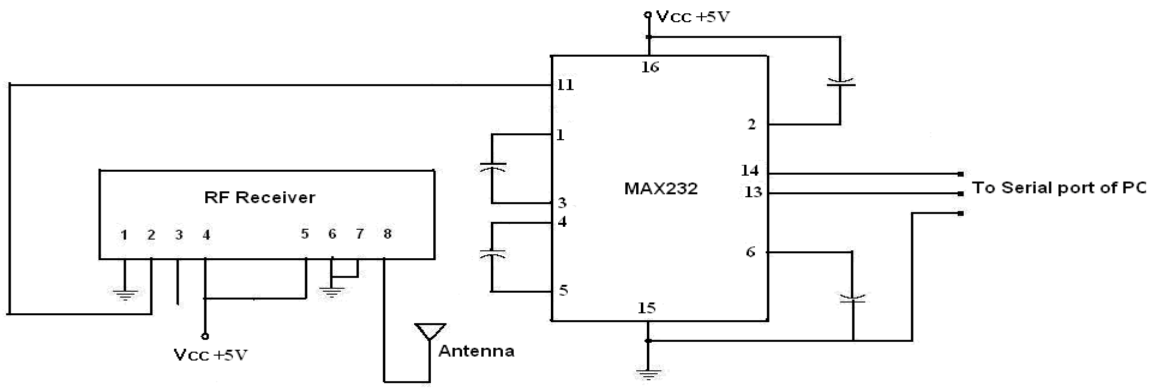

Fig. 8. RF Module interface diagram.

3. Software Details

The present system is implemented by developing a suitable embedded C program based on IAR IDE. IAR Embedded Workbench for ARM is an integrated development environment for building and debugging embedded applications. This is an integrated development environment with optimizing C/C++ compiler for ARM. It provides extensive support for a wide range of ARM devices, hardware debug systems and RTOSs and generates very compact and efficient code. Ready-made device configuration files, flash loaders. To display the data a graphical User Interface is developed using the Visual basic software. This GUI helps to study the variation of the parameters with time.

4. Results and Discussion

The embedded system is developed to measure and monitor the various parameters like atmospheric temperature, relative Humidity, atmospheric pressure and common air pollutants like CO, CO_2, NO_2, SO2 and NH_3 etc. Suitable signal conditioning circuits are designed, as the output of the sensors may not match with the ADC specifications of ARM7 processor. The signals from the sensors are fed to the on chip ADC of the ARM processor after performing the signal conditioning. This data is processed by the ARM processor and it is displayed on the LCD module. The RF module TWS 434 connected to the ARM will transmit the data to the receiver module which is connected to the PC through the MAX IC. This MAX IC will take care of compatibility of TTL signal levels. Serial communication is established between the Processor and PC using a RS232 cable. The data received by the PC is displayed on the monitor using the GUI developed based on Visual basic software.

All the measurements were carried out during the June 3rd - 18th, 2011 at the laboratory environment. The results are displayed on 2×16 LCD module and also on the computer monitor as shown in Figs. 9 and 10. The semiconductor sensors are highly vulnerable to silicon based chemicals and hence care is taken not to expose them to such conditions. All the gas sensors are calibrated using the standard static chamber method described in the literature [2, 27] so that the system can be used in real environment for the measurement of air pollutant gases. As the gas sensors have minor fluctuations to relative humidity and ambient temperatures, the availability of the temperature and relative humidity sensors to the system is very useful to monitor the performance of the gas sensors. The normal humidity and temperature levels maintained for the measurement of the various gas pollutants are between
45 % - 55 % and 25 ^{0}C - 26 ^{0}C respectively. The atmospheric pressure is found to be 101.5 kPa. With respect to small variation in temperature and humidity at the laboratory environment the atmospheric pressure is not found to vary much. Over the entire duration of measurements the pressure observed to vary between 101.3 kPa and 101.5 kPa only.

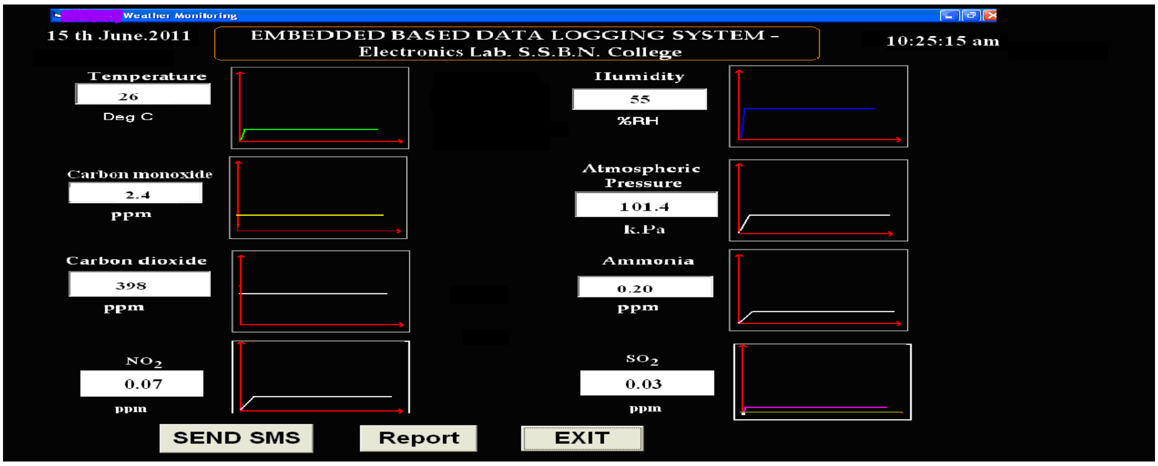

Fig. 9. GUI Display of results at Electronics laboratory.

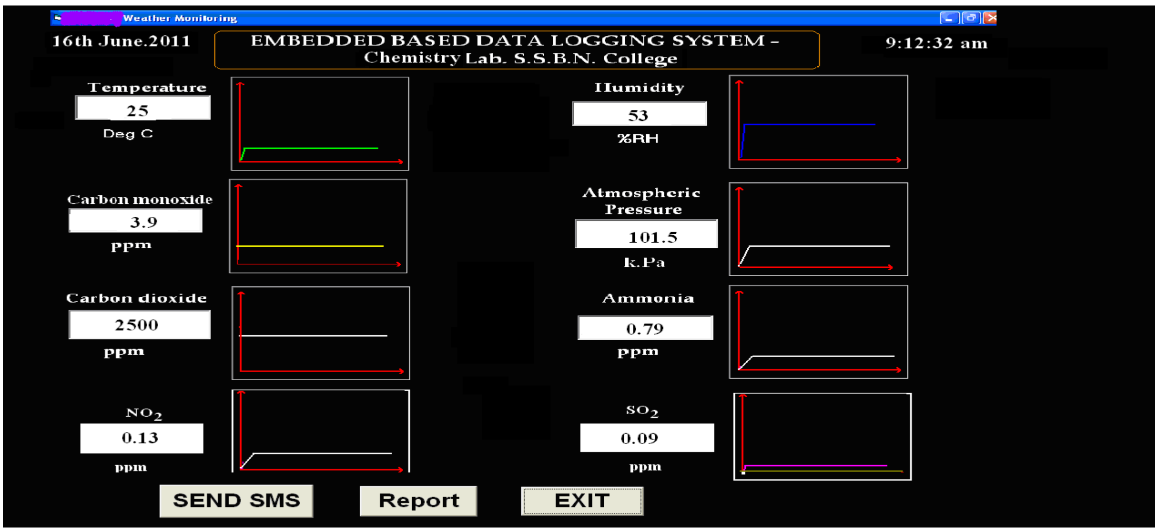

Fig. 10. GUI Display of results at chemistry laboratory.

From the graphical user interface (GUI) observations, it is clear that at the electronics laboratory environment, the CO, CO_2 levels are very low of the order of 2.4 ppm, 398 ppm respectively. Where as the NO_2 and SO_2 levels are of the order of 0.07 ppm and 0.03 ppm respectively. To observe the maximum variation we arranged the system in our chemistry laboratory and conducted some carbonate experiments. Interestingly the CO levels have increased to 3.9 ppm. Similarly when the system is kept near the exhaust pipe of our four wheeler the CO levels have increased as high as 5 ppm. Similarly to study the performance of CO_2 sensor a simple test tube experiment is performed with calcium carbonate. The reading of the CO_2 sensor increased as high as 2500 ppm. Similar observations were made for NO_2 and SO_2 gas sensors in our chemistry laboratory. They are found to be 0.13 ppm and 0.09 ppm respectively. The readings of the NH_3 sensor are found vary between 0.19 ppm and 0.58 ppm at the laboratory environment and between 0.36 ppm and 0.79 ppm in the chemistry laboratory. To get the advantage of this embedded system, the system is tested in the industrial plant area for about six hours for two days. The levels of ammonia are found to increase as high as 1.35 ppm and the levels of CO_2, NO_2 and SO_2 are found to vary according to the reported values in the literature. As the system also contains the temperature and humidity sensors, it is found that the drift in the sensor performance with Humidity and temperature is not more than 4 % in all the sensors. Some of these results are also cross-checked with those of the standard data logger Davis Vantage Vue weather station [28]. Our results are found to be well within 4 % variation. The observation of the results also indicates that no gas sensor is 100 % selective to a single gas, but produces a strong signal to the corresponding gas. The usage of the semiconductor sensors adds several advantages to the system such as low cost, quick response, low maintenance, ability to produce continuous measurements, etc. But they also suffer from lack of selectivity and sensitivity as well as higher temperatures required for use (300–500 ^{0}C). Of course to overcome such problems and to improve the stability and selectivity, and to lower fabrication costs, conducting polymers in the form of thin films, blends, or nanocomposites have been developed.

5. Conclusion

Though many workers developed this type of data loggers for the measurement and monitoring of environmental parameters, using various types of microcontrollers, this ARM based system has certain special advantages. Because of their power saving features, ARM CPUs are dominant in the embedded designs where battery operated systems play major role. For example mobile electronics market, where low power consumption is a critical design goal. Today, the ARM family accounts for approximately 75 % of all embedded 32-bit RISC CPUs making it one of the most widely used 32-bit architectures.

6. Future Scope

The efficiency and the use of the data loggers can be improved by using the wireless sensor technology by which the system will become a universally accepted one. The basic advantage of such system is, it avoids human intervention and it becomes easy to monitor the remote data logging systems for environmental studies. Also, the use of the voltage to frequency converter ICs and the single digital multiplexer with ARM controller will greatly reduce the circuit complexity. Based on the IEEE 1451.5 wireless communication protocol such wireless system is proposed and the work is under progress in our lab.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

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Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

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