Indoor Air Quality Estimation by Using Smart Sensing System

Anuj Kumar, I. P. Singh, and S. K. Sud

***Abstract*- Indoor environment air pollution measurement has become a necessity because of global warming and climate change. All across the globe researchers are trying to monitor the pollutant gases precisely in real time. Sensing system using sensor arrays has been developed to monitor indoor environment, however, these systems are costly and have not gained wide acceptance. Precise measurement of indoor environment has a huge potential in terms of energy savings. In this paper we are trying to look into the problem of real time processing of indoor environment air pollutant gases measurement using a DSP board (TMS320C6455) and then implementing it to the proposed gas monitoring system.**

***Index Terms* - Sensors array, DSP (Digital Signal Processor), Semiconductor gas sensor, VOC (Volatile Organic Compound), SPM (Suspended Particulate Matter).**

I. Introduction

Indoor environment has become an important area of research because of its influence on human health and energy consumption profile. The indoor environment affects indoor physical environment, and subsequently health and quality of life of its occupants. There is evidence showing the pathways and mechanisms by which the indoor environment factors are associated with specific aspects of physical and mental health [1,2]. The problem has become acute in recent past because of the rapid industrial growth in last half century. Due to exponential increase in industrialization, release the various chemical pollutants such as, SPM, CO, CO_2, SO_X, NO_X, VOC, Lead Aerosol and other toxics (waste water) have affected the environment and has caused, decline of atmosphere, climate change, stratospheric ozone depletion, loss of biodiversity, land degradation and stress on systems of food producing [3,4]. All these have lead to the increase in the rate of disease such as, sinusitis, asthma, pneumonitis, organic dust toxic syndrome, allergic, contact uricaria, eye irritation, nasal irritation, central nervous system symptoms, and legionnaire's disease. Rapid industrialization has lead to changes in lifestyles (greater dependence on indoor environment), an increased dependence on artificial products and advances in medicines [5].

Achieving resident comfort is the result of a combination of environmental conditions, such as air quality, indoor air temperature, relative humidity, mean radiant temperature, air velocity, illumination, sound etc. Of these the most important factors are air quality and thermal comfort of the indoor environment [ASHRAE 55-2004, ISO 7730]. Across the world, research on indoor air quality monitoring is gaining importance. A recent study has put forth that 30% – 40% of total natural resources are exploited by the buildings and almost 50% of energy resources is used to condition buildings in industrialized countries. The reality is that indoor air can be up to 10 times more polluted than outdoor air [6, 7]. Real time assessment of indoor air and thermal environment has tremendous energy saving potential. To focus on this problem we are trying to develop a real time smart sensing system using a sensor array and a DSP processor (TMS320C6455). At present we are concentrating on the major air pollutant gases such as CO, CO_2, SO_2 and NO_2. The other factors which affect indoor thermal environment, namely, temperature and humidity will be considered later.

II. Sensors

A Sensor is a device that detects or measures a real-world condition, such as motion, heat or light and converts it to an equivalent analog or digital representation [8]. In this paper we have used CO, CO_2, SO_2 and NO_2 semiconductor sensors. A gas sensor detects particular gas molecules and produces an electrical signal whose magnitude is proportional to the concentration of the gas [3]. Till date, no gas sensor exists that is 100% selective to only a single gas. A good sensor is sensitive to the measured quantity but less sensitive to other quantities [9, 10]. Available gas sensors

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are based on five basic principles. These can be electrochemical, infrared, catalytic bead, photo ionization and solid-state [11]. Table I, shows the specifications of the sensors we have used for the set-up. We have selected these sensors because they produce a strong signal for the selected variable especially at high gas concentrations with adequate sensitivity. They have a fast response time, high stability, long life, low cost, low dependency on humidity, low power consumption, and compact size [12, 13].

TABLE I
SPECIFICATIONS OF THE SENSORS USED FOR IMPLEMENTED INSTRUMENT [3, 9, 10]

Manufacturer	Type of Material	Measured Gas	Range	Model No.
Figar Gas Sensors, Japan	Semicon--ductor SnO_2	CO	30 to 1000 (PPM)	TGS2442
Figaro Gas Sensors, Japan	Semicon--ductor MMOS	CO_2	Ambient to 4000 (PPM)	TGS4161
Alphasense, UK	Semicon--ductor MMOS	SO_2	0 – 20 (PPM)	SO2 AE
Alphasense, UK	Semicon--ductor MMOS	NO_2	0 – 20 (PPM)	NO2 A1

III. MEASURING SYSTEM

The real time indoor air pollution monitoring system measures the concentrations of major air pollutant gases CO, CO_2, SO_2, and NO_2 using a semiconductor sensor array is shown in fig. 1 An analog multiplexer, filter, and signal transformer for level shifting are all included on the DSP kit. These transfer the multiple signals from the sensors to the digital signal processor (TMS320C6455). Subsequently, the output signals are fed to ADC channels and converted to a digital form. For real time processing, the data collected (CO, CO_2, SO_2, and NO_2) using the sensors is stored in DSP board memory, as well as displayed on the monitor.

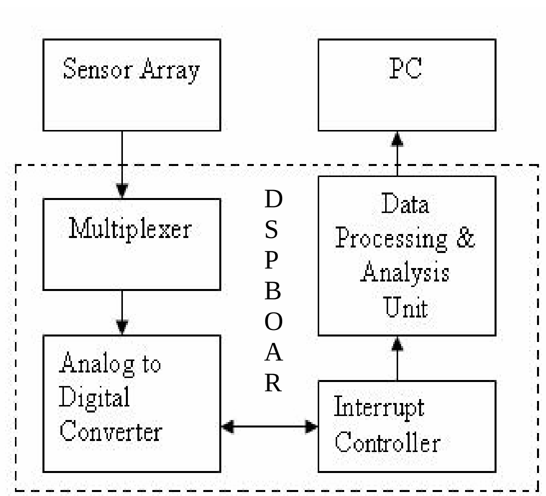


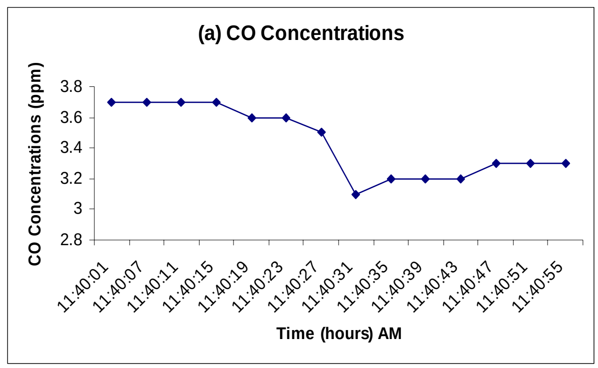
Figure 1.Block diagram of real time indoor environment air pollutant gases measurement system

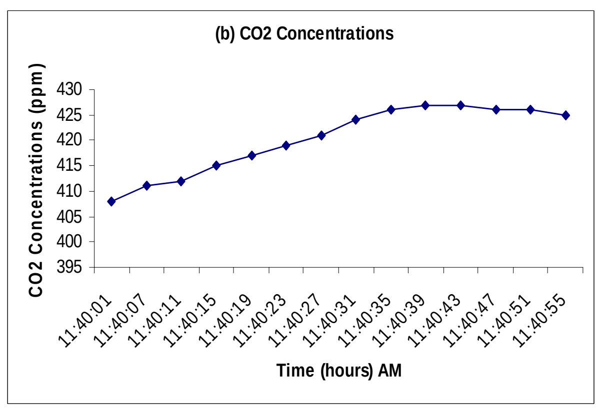
TABLE II
INDOOR ENVIRONMENT AIR POLLUTANT GASES MONITORING SYSTEM RECORDED MAJOR AIR POLLUTANT GASES CO, CO_2, SO_2, AND NO_2 CONCENTRATIONS
(30°C -35°C, 45% - 60%)

Gases Name	Average Concentration With time	Minimum Concentration (ppm)	Maximum Concentration (ppm)
CO	3.3 ppm (8h)	2.8 ppm	3.7 ppm
CO_2	399 ppm (8h)	389 ppm	422 ppm
SO_2	0.02193 ppm (8h)	0.020 ppm	0.030 ppm
NO_2	0.0072 ppm (8h)	0.004 ppm	0.010 ppm

IV. EXPERIMENTAL WORK

To carry out the experiments all the four sensors were connected through the analog multiplexer to the DSP board. Table II represents the results of measured concentrations of air pollutant gases CO, CO_2, SO_2, and NO_2.





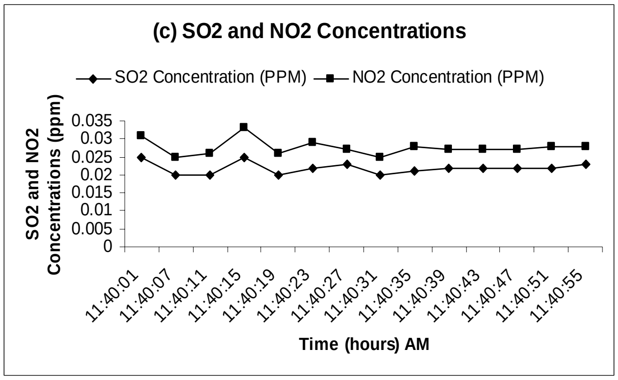


Figure 2 (a, b, c). Concentrations of air pollutant gases for indoor environment (30°C -35°C, 45% - 60%).

V. RESULTS AND DISCUSSION

The idea behind this study is to monitor the indoor air quality in real time with fair accuracy. The sets of field measurements readings of CO, CO_2, SO_2, and NO_2 sensors were recorded at a normal laboratory environment. Fig. 2 (a, b and c) shows the concentration levels of CO, CO_2, SO_2, and NO_2 in the laboratory over a certain period of time (March 2008) and the measurement procedure was carried out when the temperature was in the range of 30°C-35°C, while the relative humidity was in the range of 45%-60%. This indoor environment air pollution gas measurement system successfully measures the concentration of air pollutant of indoor environment (without controlling the temperature and relative humidity). The sets of field measurements of CO, CO_2, SO_2, and NO_2 sensors were recorded at Mechatronics laboratory, IDDC, IITD. The average values of CO, CO_2, SO_2, and NO_2 concentrations of temperatures 30°C-35°C and relative humidity 45% - 60% is 3.3ppm (8h), 399ppm (8h), 0.02193 ppm (8h), and 0.0072ppm (8h) respectively. To verify these results, data generated with standard data loggers (HOBO), were compared with the data of indoor environment air pollution gas measurement system. Data recorded by indoor environment air pollution gases measurement system shows reasonable accuracy with ± 3% variation to standard data.

VI. CONCLUSION

The indoor environment air pollutant gases monitoring system has been successfully implemented in compliance with the DSP TMS320C6455 board. The semiconductor gas sensors can be used to monitor the target gas concentrations. The usage of the semiconductor sensors adds several advantages to a system such as low cost, fast response, low maintenance, user friendly and ability to produce real time measurements. A DSP board makes the system to be used for real time application. The implemented system is successful in measuring the concentration of air pollutant gases. Initial results of the study are encouraging. But this has its own limitations, as these results are based on small number of measurements. To increase the level of accuracy we are planning to conduct more measurements in different conditioned environments. Then we will try to couple this system with the air conditioning system. If this is done successfully, we will be able to increase the effectiveness and efficiency of the air conditioning system in near future.

VII. FUTURE IMPROVMENTS

1. This Indoor Environment air pollutant gases monitoring system needs some more field work and field experiments to increase the accuracy level.
2. A relative humidity sensors and a temperature sensor could be added to simultaneously monitor the relative humidity and temperatures values.
3. We will make this system compliance to IEEE 1451 standard and will also incorporate IEEEP 1451.5 standard.

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