Design Embedded System for Monitoring Carbon Dioxide Gas

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Abstract **- Design a high performance, portable sensor module to sense the physical parameters is need of hour. Therefore, based on an embedded technology deploying of advanced microcontroller and implementing own prepared ferrite sensor for development of smart sensor module for detection of CO_2 gas and discussed in this paper. The nano sized Nickel-Zink ferrite material synthesized by co-precipitation and confirmed formation of single-phase compositions by x-powder diffraction (47nm). The thick film carbon dioxide gas sensor is designed by screen printing technique on glass substrate and implemented for design sensor module. The electrical resistance (R) measured against constant operating temperature with variable concentration of CO_2 gas in % unit and shows results decrease with increases in the concentration of CO_2 gas in %. On inspection of this data, it is found that, the synthesized composition is sensitive to Carbon dioxide (CO_2) with very fast reverse recovery at specific temperature know as operating temperature. Using prepared CO_2 gas sensor, signal conditioning is designed about TLC271. Deploying on chip resources of the AVR Atmega16 microcontroller an embedded system is designed to produce the CO_2 data in % unit. The software is developed in embedded C, wherein calibration of the signal to engineering unit is emphasized. The output of the system provides in various manner to enhance the smartness of the present sensor module and obtained results discussed in this paper.**

Index Terms **- Sensor Module, Embedded System, Thick Film Sensor, Electrical Resistance, Carbon dioxide Sensor.**

I.INTRODUCTION

The rapid evolution in the field of electronic instrumentation, specifically for monitor and control various environmental parameter precisely for various applications. The applications such as, Agricultural Instrumentation, Industrial automation, food processing, Automobile and Biomedical Instrumentation etc [1]. Due to this, the field of design smart sensor module is emerging. The IEEE technical group has also defined standards for intelligent sensor module with the title as IEEE 1451 standards [2]. The sensor technology is the core technology and producing the sensors based on physical transduction only. These sensors are rarely having analog as well as digital signal processing units. The modern instrumentation depicts the need of plug-and-play modules of promising features. This leads to emergence of novel concept of Smart Transducer Interference Module (STIM) or Smart Sensor Module (SSM). Implementation of smart sensor module embedded technology enhances the features of the device. Recently, the field of embedded system development is becoming more pervasive for various applications [3]-[4]. An embedded system provides suitable solution to enhance the smartness of the system [5]-[6]. Therefore, to keep pace with the state of art of present electronic instrumentation, the smart sensor module is designed for monitoring of Carbon dioxide gas. The sensors are developed in the laboratory by using compositions of polycrystalline nanoferrites as sensing materials and deploy for gas sensor application. Therefore, design and development issue of sensor module for measurement of Concentration of CO_2 gas is also discussed here.

II.DEVELOPMENT OF CO_2 SENSING MATERIAL AND SENSOR

Electrical properties of the polycrystalline spinel ferrite revels the materials suitability for sensor based application. Therefore, the polycrystalline spinel ferrites have been synthesized using co-precipitation method and used to develop the sensor. The compositions of polycrystalline spinel ferrite with chemical formula, $Ni_xZn_{1-x}Fe_2O_4$ (x = 0.2, 0.4, 0.6 and 0.8). To investigation of electrical properties and designing of smart sensor module, ensuring an embedded technology, the compositions of the ferrites under investigation are shaped as per the requirement.

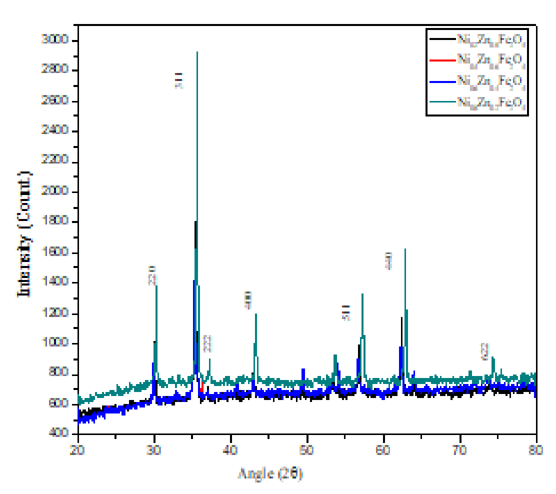

Figure 1. X-ray diffraction for composition of $Ni_xZn_{1-x}Fe_2O_4$ (x=0.20, 0.40, 0.60 & 0.80)

For confirmation of structural details material characterized by standard tool X- ray diffraction for confirmation of structural details [7]. Figure 1 shows the X-ray diffraction for composition of $Ni_xZn_{1-x}Fe_2O_4$. On investigation, it is proved that, the compositions of polycrystalline ferrite materials reveal the phenomenon of chemisorptions at elevated operating temperature [8]. This surface phenomenon causes to favour the gas sensing mechanism.

III.DESIGNING OF SENSOR MODULE

A sensor module is designed using AVR Atmega16 microcontroller, wherein the sensing element developed by using NiZn polycrystalline spinel ferrite.

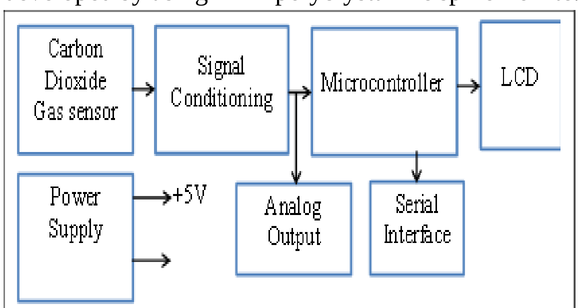

Figure 2: Block Diagram of Sensor node

The Sensor module is specially designed for detection of CO_2 gas and it is the realization of embedded technology [9]. Therefore, both hardware as well as software is equally important. Figure 2 shows the block diagram of sensor node for monitoring of concentration of CO_2 gas. The hardware is designed about AVR ATmega8L microcontroller. Moreover, the firmware is developed by using Code Vision AVR as IDE. Based on different bus protocols the sensor module is facilitated with different kinds of outputs, which may be suitable for IOT application [10]-[11]. The design issues are discussed here with Hardware & firmware of Sensor Module.

A. Carbon Dioxide Gas Sensor

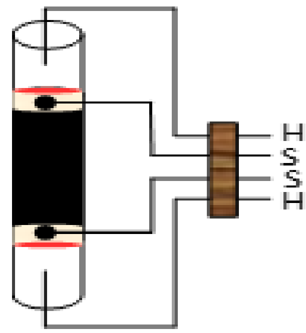

Figure 3: Polycrystalline ferrites Based sensor for carbon dioxide gas.

The Sensor Module is designed to monitor the carbon dioxide gas. Therefore, it is proposed to synthesize the sensing material suitable for gas sensing applications. A thick film of sensing material is deposited on cylindrical glass tube as shown in figure 3 and exposed to the CO_2 gas of variable concentration from 0.1 % to the 15% and resistance of the sensing element (R_{CO2}) is measured. At the beginning operating temperature is set to for maximum sensitivity. At which temperature the sensor gives maximum response which is called operating voltage. It if found that at 250 ^{0}C maximum sensitivity. Setting the operating temperature at variable concentration of CO_2 gas change in resistance measure[8]. It is found that increasing the concentration of CO_2 gas resistance of the sensor decreases. This behavior consider for designing signal conditioning stage. Therefore sensor used in resistive type. The heating element (HH) is along the axis of the cylindrical tube. The operating temperature plays significant role on the performance of the sensor. The heating element is powered by separate supply. The current through heating element depends upon the operating temperature. Sensing element.

B. Signal Conditioner stage For CO_2 Gas

The Sensor Module is designed for monitoring carbon dioxide gas. The ferrite materials, the carbon dioxide gas sesnor is designed and implemented. This is resistive sensor. A change in resistance is reported due to existance of CO_2 gas. The sensor circuit is wired in resistive divider configuration and resulting emf V_{G1} (in mV) is used for further processing. This voltage is strengthened by specific signal condition circuit. Employing operational amplifier of TLV 271 the circuit is designed. The circuit is wired to configure the gain as unity. Basically, the step size of ADC is very small about 2.56 mV. Therefore, an ADC can take small signal to ensure the preciseness. Hence, voltage amplification stage is not required.

C. Microcontroller Unit of an Embedded System:

According to the definition of the Smart Sensor Module, the configurable device such as microcontroller or FPGA is an inherent part. As Sensor Module reveals embedded technology, the deployment of microcontroller plays significant role on the intelligence of the module. The salient features of microcontroller decide the reliability of the sensor module. Moreover, it also provides the solution to establish interface between STIM and NCAP by incorporation either wired or wireless platform for data communication [9, 10]. On literature survey, it is found that, the microcontrollers from various families are available. However, deploying the microcontroller AVR ATmega 8L the computational part of the present Smart Sensor Module is developed. This microcontroller is small in size and exhibit low power consumption. It depicts, smart on chip resources, by availing which an embedded design can be realized. To design SSM, the microcontroller should be facilitated with on chip data converters.

IV.DEVELOPMENT OF FIRMWARE FOR SENSOR MODULE

Present t Sensor Module is the realization of an embedded system, wherein firmware is equally important. Along with the hardware, embedded firmware helps to introduce networking capabilities, due to which the module can be deployed in the IOT environment [11]. Therefore, such SSM is well suited for long term industrial environmental data acquisition for IOT representation [12]. With rapid development of IoT, major manufacturers are dedicated to develop multi-sensor acquisition interface equipment. The algorithm reveals sequential execution of the functions designed for dedicated task. Along with the main function, the firmware reveals following functions. These functions establish the thread with hardware resources. It also ensures the inter-function data transfer. These functions are sequentially called into main program.

1. Analog to digital conversion [ADC (channel)]
2. Detection of CO_2 gas [data_from_Channel_2]
3. Decimal to BCD and ASCII conversion [(dec-bcd)]
4. Initialization of LCD [lcd_init( )]
5. Character display [lcd_display]
6. Parameter value display [LCD( )]
7. Configuration of LCD[LCD cmd ( )]
8. Sending data to LCD[LCD data( )]
9. Sending data to Serial_port[Serial data( )]
10. Delay Function [Msdelay( )]

Detection of CO_2 gas [data_from_Channel_2] function is defined for detection of the carbon dioxide gas and display. The analog voltage appeared at this channel is converted in percentage unit by putting calibration expression (1) a display the output.

V.RESULT AND DISCUSSION

The Sensor Module is designed for monitoring of carbon dioxide gas. Such type of module finds tremendous application in the high-tech agriculture, wherein polyhouse system is ensured. Environmental carbon dioxide gas monitoring system helps to provide controlled environment to the crop [13].

It is known that, these sensors are resistive sensors and resistance sensor increases with increase in the concentration of the carbon dioxide gas. The signal conditioning circuit provides proportional analog voltage in mV. This analog voltage (V_{G1}) is read into the AVR microcontroller for digitization and further processing. In fact, as per IEEE 1451 standard, the output must be is digital domain and should in the form of scientific units. To achieve the output in scientific units, it has to be calibrated by employing standard means. For calibration, process of regression and fitting to the get empirical relation, is always recommended.

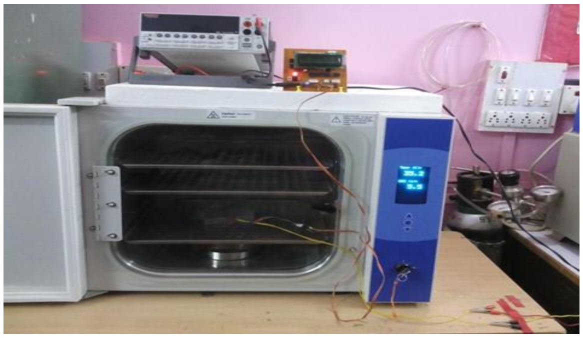

Figure 4: Experimental arrangement for calibration of the sensor module for CO_2 in %.

For calibration of the Smart Sensor Module, the sensor under investigation is exposed to the carbon dioxide gas of variable concentration in % unit. The carbon dioxide gas, in controlled manner, is applied by employing sophisticated Carbon Dioxide gas Chamber from, Thermo Scientific, USA. An experimental set up used is shown in figure 4. The temperature of the sensing element is controlled to the operating temperature of 175 ^{0}C. The resulting emf (V_{G1}) in mV is recorded. The observed voltages V_{G1} (mV) are plotted against concentration of CO_2 gas in % unit and depicted in figure 5. On inspection of figure 5, it is found that, the observed emf decreases with increase in the CO_2 concentration. This can be attributed to the increase in the resistance of the sensing element with increase in the carbon dioxide gas [14]. The observed data is analyzed with regression process and fitted with the straight line. The empirical relation observed from fitting process is

V_{G1} (mV) = - 9.597 x C_{CO2} + 1589.33 (1)

Where, V_{G1} is the carbon dioxide gas dependent emf and C_{CO2} is the concentration of carbon dioxide gas. This equation is reduced to

Concentration of CO_2 gas (%) = (1589.33-V_{G1})/ 9.597 (2)

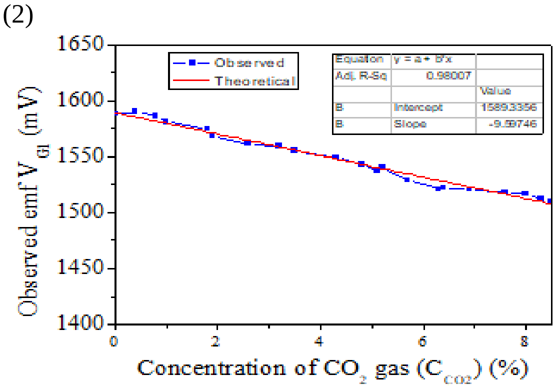

Figure 5: Graph of observed emf (V_{G1}) in mV against Concentration of carbon dioxide gas (C_{CO2}) in % unit.

This equation 2 is employed in the firmware for calibration of the system. The function is continuously called into main program. This system gives observations regarding concentration of carbon dioxide gas continuously on the display unit. The smart sensor module under investigation is facilitated with the analog port also. Therefore, analog voltage VG1 is made available for the designer for further instrumentation. After calibration the SSM is subjected to the measurement of CO_2 gas. The data obtained from the system under investigation shown in table 1 and that of given by standard instrument show match with acceptable deviations. Thus, the Sensor Module is ready for further deployment

Table1. Concentration of CO_2 gas shown by the System

CO_2 gas shown by the sophisticated Carbon Dioxide gas Chamber (in %)	CO_2 gas shown by the system under investigation (in %)
0.5	0.43
1.0	0.95
1.5	1.52
2.0	1.93
2.5	2.31
3.0	3.12
3.5	3.61
4.0	4.09
4.5	4.51
5.0	4.87
5.5	5.57
6.0	6.09
6.5	6.47
7.0	7.01
7.5	7.62
8.0	8.13
8.5	8.53
9.0	8.92

VI.CONCLUSION

Ensuring an embedded technology a Sensor Module is developed to monitor the concentration of carbon dioxide in percentage unit. Present sensor module is calibrated to the respective scientific unit by using standard process of regression. The empirical relations obtained are used in the firmware. This enhances the intelligence of the module. The module is also implemented to the monitor respective parameters. Results shown by the system under investigation shows close agreement with that of obtained from standard instrument. It can be concluded that, Smart Sensor Module, designed to monitor the environmental parameter, is highly reliable and precise.

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