International Journal of Electrical Electronics & Computer Science Engineering
Volume 5, Issue 1 (February, 2018) | E-ISSN : 2348-2273 | P-ISSN : 2454-1222
Available Online at www.ijeecse.com

Development of an Embedded System for Measurement of Temperature Based on Polycrystalline Ferrite Material

S.N. Patil[1], A. M. Pawar[1], S. K. Tilekar[2], B. P. Ladgaonkar[2]
[1]Department of Electronics, Tuljaram Chaturchand College, Baramati, Dist. Pune, Maharashtra
[2]Department of Electronics, Shankarrao Mohite Mahavidyalaya, Akluj, Dist. Solapur, Maharashtra
suhas.patil05@gmail.com, aparnapawar21@gmail.com

***Abstract:** Designing of smart sensor module, of high performance, large adoptability, portability to sense the physical parameters is highly essential for electronic measurement instrumentation. Therefore, based on an innovative technology of advanced microcontroller a smart temperature sensor module is designed and presented in this paper. The composition of nano sized (40nm) Nickel-Zink ferrites are synthesised by co-precipitation and formation of single phase compositions are confirmed by x-powder diffraction. The thick film sensor is designed by screen printing technique and implemented for sensor module development. The electrical resistance (R) measured against temperature shows exponential decrease with increase in the temperature in ^{0}C. On inspection of this data, it is found that, the synthesized composition is mostly sensitive to temperature with very fast reverse recovery. Using this thick film of the compositions as temperature sensor, signal conditioning is designed about TLC271. Deploying on chip recourses of the AVR microcontroller an embedded system is designed to produce the temperature data in ^{0}C. The use of on-chip ADC not only reduces the hardware complexity but also increase the preciseness due to 10-bit resolution. The software is developed in embedded C, wherein calibration of the signal to engineering unit is emphasized. This helps to enhance the portability of the present sensor module.*

***Keyword:** X-Powder Diffraction, Polycrystalline Ferrite, Thick Film Sensor, Electrical Resistance, Temperature Sensor, Embedded System.*

I. INTRODUCTION

Recent trend is to employ smart electronic modules to develop the instrument of desired features. Therefore, the researchers are showing interest in the design of smart electronic module of dedicated features, wherein the technology such as embedded technology is employed. The development of smart sensor module is one of the areas of electronic system design. The sensor required for measurement of the humidity, temperature, concentration of various environmental gases etc are need of the present day measurement instrumentation for diverse applications [1]. It is known that, temperature is one of the most significant environmental parameter. Therefore, it is essential to monitoring and control. Particularly, in the field of chemical industries, paper industries, precision agriculture, storage plants, home appliances, smart cars etc the monitoring of the temperature plays vital role [2]. In fact, to realize the HVAC system the temperature should be essential controlled [3]. Therefore, it is need of hours to design cost effective a smart sensor module for this dedicated application. Therefore, in present research work, it is proposed to develop a sensor module for temperature measurement. It is also proposed to design the sensors and then deploy it for above purpose. On survey, it is found that, the ferrite materials exhibit the electric conductivity and its sensitivity to vary with physical parameters [4-6]. For design of sensor, the sensing material of required features is essential, which can be synthesized by availing techniques of materials` research. Thus, the research work undertaken comprises synthesis of electronic material and designing of the sensor using various techniques, development of sensor module and implementation of the same. The details regarding various technologies, involved in the present research are studied and described in this paper.

II. DEVELOPMENT OF SENSOR AND SENSOR MATERIAL

Along with promising magnetic properties, the ferrites show interesting electrical properties. Therefore, many researchers are showing interest in investigation of ferrite materials suitable for electronic sensor development. On investigation of temperature sensitive electric properties, it is proved that, polycrystalline spinel ferrites exhibiting semiconducting nature, are suitable for development of temperature sensor [7-9].

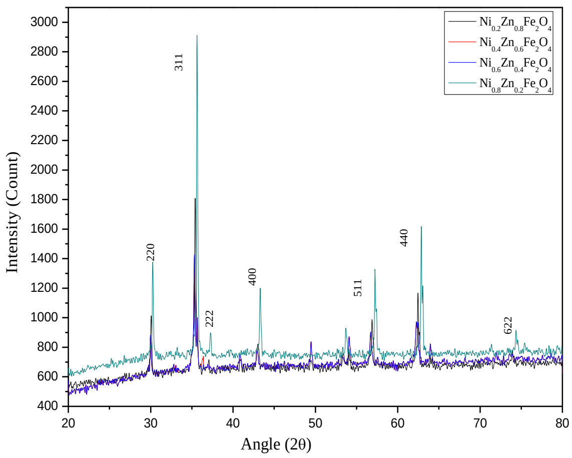

Fig. 1. X-Ray Diffraction for Composition of $Ni_xZn_{1-x}Fe_2O_4$ (x=0.20, 0.40, 0.60 & 0.80)

The temperature Sensor designed by using $Ni_xZn_{1-x}Fe_2O_4$ ferrites. The compositions of polycrystalline spinel ferrite have been prepared by using co-precipitation method. To explore the structural details of the compositions under investigation, the standard X-

Ray powder Diffraction (XRD) tool is used for structural investigation of the materials under study.

X-ray diffractograms of polycrystalline powdered compositions of $Ni_xZn_{1-x}Fe_2O_4$ (x = 0.2, 0.4, 0.6, 0.8) ferrites were obtained from powder diffractometer. A diffractograms for composition is shown in the figure 1. The diffractograms have well defined reflections without any ambiguity, with (311) as a prominent reflection, which is a prime characteristic of the spinel structure. This suggests the formation of cubic spinel structure for all compositions. This confirms the formation of spjnel ferrites [4]. By using screen painting technology the thick film of the compositions is deposited on ceramic substrate.

The thick film is deposited, using screen printing technology, on the ceramic and glass substrate [10-11]. The silver paste is pasted to achieve Ohmic contacts. The silver electrode is used to facilitate the connection of the same to electronic circuits. The present temperature sensor is passive. The resistance of the material exponentially decreases with increasing temperature. This property is utilized in this design. Therefore, the present sensor is of resistive type. Hence, it helps to improve the response times. Since, the sensor is passive in nature, it is excited by +5V supply [12]. To achieve good stability in the output, it is recommended to employ highly stable and noise free power supply. While interfacing this sensor module to the further electronic instrumentation, the designer must take care of the power supply of the instrument.

III. TEMPERATURE DEPENDANT DC ELECTRICAL RESISTIVITY MEASUREMENT

On confirmation of formation of single phase compositions of nano particles, it is essential to investigate the electric properties [13]. These properties are depends upon environmental parameters, preparation conditions, nature of compositions and so on. Therefore, temperature dependent electrical resistivity properties were investigated. The electrical resistances (Rt) for these prepared sensors are measured with the temperature (t) from 30^{0}C to 150^{0}C and graph of resistance against temperature is depicted in figure 2. These graphs help to confirm the range of temperatures for which the devices could be suitably deployed. From results of this intensive study, it is found that, the compositions are showing negative temperature coefficient of resistance and are suitable for designing the sensing element for temperature sensor. It is known that, this thermistor like nature support to design temperature sensor.

From inspection of these graphs, it is found that, for x = 0.20 and x = 0.40 are most suitable for development of sensors for temperature range from room temperature to 100 ^{0}C. The sensor, developed by employing compositions for x = 0.60 and x =0.80, reveal their suitability for upper range of temperature.

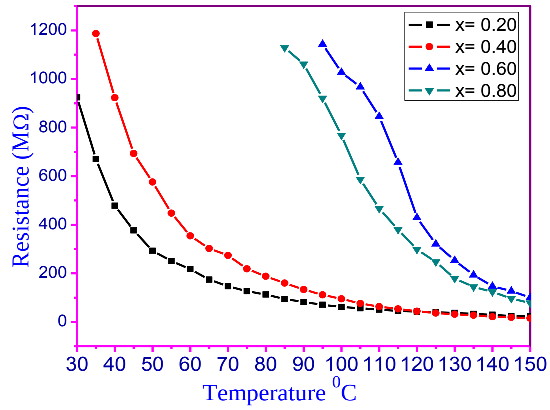

Fig. 2. Graph of Resistance (R) against Temperature (t) in ^{0}C for Thick Film of Compositions $Ni_xZn_{1-x}Fe_2O_4$ Deposited on Ceramic Substrate

With suitable electronic circuit, these sensors can also be deployed for lower range of temperatures. Highly precise digital meter, Tektronix Make model DMM4050, 6.5 Digit Resolution, Accuracy is employed to measure the resistance of the prepared sensor. The digital thermometer is used to measure temperature in degree centigrade. By developing software the exponential response can be essentially linearized to realize the process of calibration and implementation.

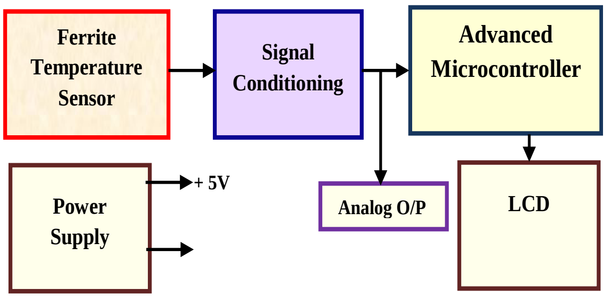

Fig. 3. Block Diagram

IV. DESIGN OF SENSOR MODULE

Sensors are used in many devices and systems to provide information of the parameters being measured or to identify the states of control. To enhance the reliability and preciseness of the sensor module sensing material is synthesized and deploy for sensor module design. A sensor module is designed about AVR microcontroller. Figure 3 depicts the block diagram of present system.

A. Temperature Sensor:

Based on compositions of polycrystalline $Ni_{0.2}Zn_{0.8}Fe_2O_4$ and $Ni_{0.4}Zn_{0.6}Fe_2O_4$ ferrite materials as sensing materials, a temperature sensor is developed, wherein screen printing technique is employed to deposit thick film of above sensing materials.

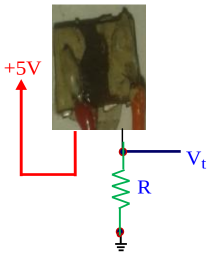

Fig. 4. Photograph of Temperature Sensor Designed for Realization of SM

The photograph of temperature sensor is depicted in figure 4. It is resistive sensor and revealing semiconducting behaviour with applied temperature. As per the requirement the sensor is designed for monitoring of environmental temperature. As shown in figure 4, it is used in resistive divider combination, which is powered by +5 Volt. Therefore, it provides DC voltage depending upon temperature of the surrounding in ^{0}C and connected to the signal conditioning stage.

B. Signal Conditioning and Output Stage:

The signal Conditioning Stage is design using TLC271. Output of signal conditioning stage is given to first channel of on chip ADC of AVR microcontroller. To enhance smartness of the module beyond the standard module, the display unit is designed about Smart LCD to display temperature in ^{0}C.

C. Software:

After successfully design of hardware, software is design to realize embedded technology to enhance the smartness of the module. According to embedded philosophy, to process necessary information and to synchronize the operation of on-chip as well as off-chip resources, the firmware is required. Employing CodeVision AVR, an IDE, the firmware is developed in embedded C environment.

V. CALIBRATION OF SENSOR MODULE

To present the values of the parameters in respective, one has to calibrate the Sensor Module to convert the data into respective scientific unit. In the beginning, for calibration of the Sensor Module to real unit, the degree celcius, the temperature dependent emf (V_T) is measured and plotted against temperature from 30^{o}C to 100^{o}C. An experimental set up used is shown in figure 5. The temerature dependent emf is recorded at output of signal conditioing stage. On inspection of figure 5, it is found that, calibration can be ensured with the use of piecewise approximation[14,15]. The graph of V_T against t shown ifn figure 6 can be divided into two regions. The regions are decided from slope of the graph. The first region is from 30 ^{0}C to 60 ^{0}C and second regions is from temperature is from 60 to 100 ^{0}C. The graph is fitted by process of regression for both regions. The realization piecewise fitting to straight line is depicted in figure 7. The process of data fitting results into the relations:

Fig. 5. Experimental Arrangement for Calibration of the SSM for Temperature in ^{o}C

Temperature (t) ^{O}C = $((V_T - 136.0)/9.335)$ (1)

Temperature (t) ^{O}C = $((V_T + 532.7)/20.83)$ (2)

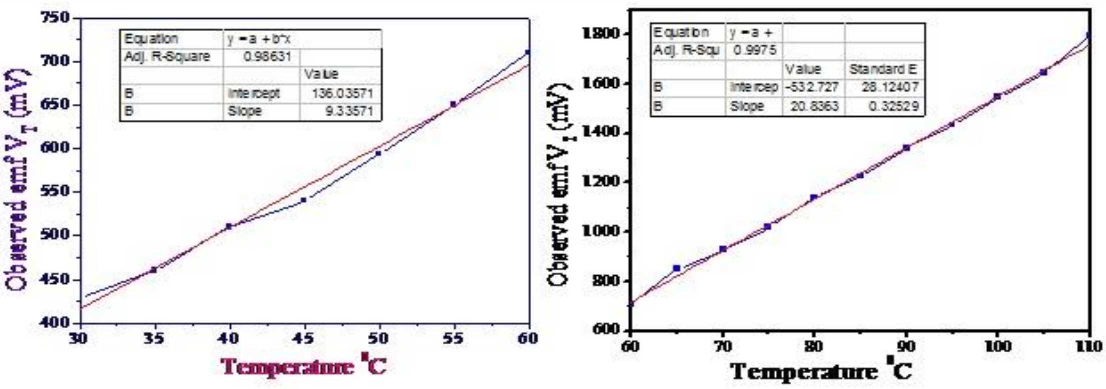

Fig. 7. The Graph of Observed emf (V_T) in mV Against Applied Temperature in ^{o}C

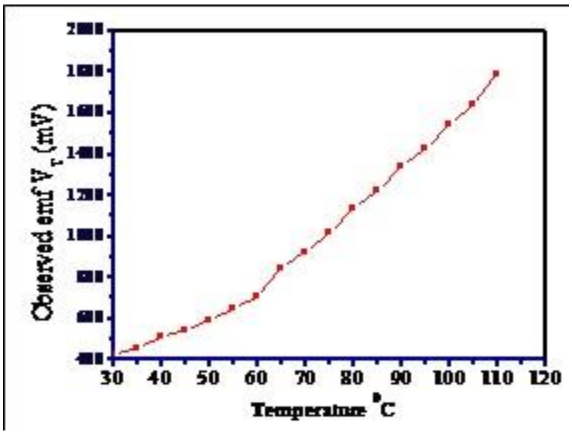

Fig. 6. The Graph of Observed emf (V_T) in mV against applied Temperature in ^oC

Where, V_T is temperature dependent emf. These equations, eq. 1 and eq. 2, are employed in the firmware for calibration of the system. The function is continuously called into main programme. This system gives temperature reading continuously on the display unit. Thus, system is providing output temperature in the ^0C scale. The sensor module under investigation is facilitated with the analog port also. Therefore, analog voltage V_T is made available for further instrumentation.

For validation of the calibration, the Smart Sensor Module is subjected to the process of standardization. To ensure standardization, the system is implemented to measure the temperature in degree centigrade. The temperature data shown by system under investigation and that of obtained from standard thermometer and

Table 1. Temperature Data Shown by System Under Investigation and that Obtained from Standard Thermometer and Digital Meter.

Temperature shown by the standard thermometer in ^0C	Temperature shown by the standard digital meter DM-97 in ^0C	Temperature shown by the System under investigation in ^0C
30	29	29.31
35	34	34.36
40	40	40.41
45	46	46.09
50	50	50.11
55	55	49.97
60	60	60.03
65	65	65.17
70	70	70.01
75	75	75.11
80	81	80.75
85	86	85.79
90	90	90.19
95	95	95.21

Scientech digital temperature meter model DM-97 are presented in Table 1. From table 1, it is found that the temperature data obtained from the present sensor module and that of shown by standard instruments are closely matched. Thus, system is calibrated to the temperature in ^0C. Now, the Sensor Module is ready for further implementation to the monitoring of the temperature.

VI. CONCLUSION

It can be concluded that, as per the objectives, the composition of spinel ferrites have been synthesized and deployed as sensing element for sensors designed for the temperature. It is also concluded that, deploying these sensors Sensor module of prominent features is developed to monitor. The Sensor Module works with great reliability and depicts result with preciseness.

VII. REFERENCES

[1] S.N. Patil, B.P. Ladgaonkar, "Synthesis and Implementation of $NiZnFe_2O_4$ ferrites to design embedded system for humidity measurement", Int. J. Adv.Res. Elctron. Instrum. Eng. 2 (8) (2013) 3813–3821.

[2] Kavi K. Khedo, Rajiv Perseedoss and Avinash Mungur, "A Wireless Sensor Network Air Pollution Monitoring System", International Journal of Wireless & Mobile Networks 2 2 (2010) 31-45

[3] A.M. Pawar, S. N. Patil, A. S. Powar and B. P. Ladgaonkar, "Wireless Sensor Network To Monitor Spatio-Temporal Thermal Comfort Of Polyhouse Environment", International Journal of Innovative Research in Science, Engineering and Technology, 2 10 (2013) 4866-4875.

[4] S. N. Patil, A.M. Pawar, S.K. Tilekar, B.P. Ladgaonkar, "Investigation of magnesium substituted nano particle zinc ferrites forrelative humidity sensors", Sensors and Actuators A 244 (2016) 35–43

[5] E. Rezlescu, N. Iftimie, P. D. Popa and N. Rezlescu, "Porous nickel ferrites for semiconducting gas sensors", J. Phys. Conf. Ser. 15 (2005) 51-54.

[6] V. L. O. Brito, L. F. A. De Almeida, A, K, Hirata and A. C. C. Miglian , " Evaluation of NiZn ferrites for use in temperature sensors", Progress in Electro. Magn. Res. Letters, 13 (2010), 103-113.

[7] A.Y Lipare' ' ,P.N Vasambekar, A.S Vainganka r, "Dielectric behavior and a.c. resistivity study of humidity sensing ferrites", Materials Chemistry and Physics, 81 1 (2003)108–115.

[8] N. Rezlescu' , C. Doroftei, E. Rezlescu and P.D. Popa, "Structure and humidity sensitive electrical properties of the Sn^{4+} and/or Mo^{6+} substituted Mg

ferrite", Sensors and Actuators B: Chemical, 115 2 (2006)589–595.

[9] U. Sarma and P. K. Boruah, "Design and development of a high precision thermocouple based smart industrial thermometer with on line linearisation and data logging feature", Measurement 43(2010)1589–1594.

[10] Bhimrao P. Ladgaonkar and Suhas N. Patil and Shivprasad K. Tilekar, "Development of Ni-Zn Ferrite based smart humidity sensor module by using mixed signal programmable System-on-chip", Applied Mechanics and Materials, 310 (2013)490-493.

[11] S. N. Patil and B. P. Ladgaonkar, "Synthesis and implementation of $NiZnFe_2O_4$ ferrites to design embedded system for humidity measurement", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 2(8)(2013) 3813-3821

[12] S. N. Patil, A. M. Pawar and B. P.Ladgaonkar, "Synthesis and Deployment of Nanoferrites to Design Embedded System for Monitoring of Ammonia Gas", International Journal of Advances in Engineering & Technology (IJAET),6(2017)27-31

[13] A. Munir, F. Ahmed, M. Saqib and M. Annis Ur Rehman, "Electrical Properties of Ni Zn Nanoparticles prepared by simplified sol gel method",J. Super Cond. Nov Magn., 28(2015)983-987.

[14] A.A. Ayman, and A.S.A .Ei-Lail, "A novel circuit for thermocouple signals linearization using AD converter". IJITCS, 3(2013)56–60.

[15] Datasheet of AVR Atmega 8L Microcontroller.