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Microcontroller Pic 18f4550 Based Wireless Sensor Node to Monitor Industrial Environmental Parameters

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Abstract - The paper deals with the design and development of Wireless Sensor Node for Wireless Sensor Network for monitoring the industrial parameters. Wireless Sensor Network (WSN) is an innovative technology for monitoring of wide area. Emphasizing the monitoring environmental alcohol gas concentration, the Wireless Sensor Network is designed, wherein the MQ-3 is employed to sense the alcohol gas. Ensuring the need of high input impedance, the TLV2774A is used to wire the signal conditioning stage. Configuration of on-chip ADC of 18F4550 to 10 bit resolution realizes the preciseness in the data. The present node is also designed to monitor the temperature of the localized area with significant accuracy. Deploying standard method, the nodes are calibrated to the real unit and standardized with sophisticated device. Deploying CCS for PIC, the IDE, a firmware is designed in embedded C environment. Each node on inclusion in the network communicates with the co-ordinator node with their own ID. The Wireless Sensor Network operates with good reliability and provides the data of the parameters at the base station in real time.

Keywords - Wireless Sensor Network, RF module ZigBee, PIC 18F4550 microcontroller, Industrial Parameter, Embedded Technology.

I. INTRODUCTION

Wireless Sensor Network (WSN) [1], is an ubiquotous field of electronic instrumentation, which comprises both instrumentation as well as communication technologies and operates within Industrial, Scientific and Medical (ISM) band. Following IEEE 802.15.4 standards, the Wireless Sensor Networks collaboratively operate to collect and dessiminate data with great security and reliability. Therefore, it plays vital role in measurement and control of environmental parameters of industrial and agriculture sectors as well. It deserves key role not only in biomedical field but also in military and security fields. The Wireless Sensor Network (WSN) system consist of devices, which sense the signal, process and transmit the signal to base station. The base station plays the jobs of not only as data logger but also of data analysis and prediction. Each of these devices is known as sensor node [2], that comprises a sensor or array of sensors, Data Acquisition System (DAS), processor, RF module and power supply unit. Moreover, the smart motes are also associated with the Global Positioning System (GPS) [2], to indicate their location in the monitored area. The movable robotic system can also provided with every smart mote to vary its location and to collect data from different place. Wireless Sensor Network is the network of devices called as wireless sensor nodes, routed cooperatively to exchange information, through wireless link. The Wireless Sensor Networks, consist three types of nodes as **coordinator**; which organize the network and helps to maintain routing tables. **Routers**; routers communicate with coordinator and other routers to reduce functions of end devices and provides path for end devices to communicate data to the base station or coordinator. **End Device**; End devices ensures the interfaces to the physical world. It senses the parameters for which it has been designed and communicates with coordinator through desired routing protocol and forward signal to the base station.

The communication protocols are more complex and designed according to suitable criteria. Following are the characteristics of Wireless Sensor Network.

- Low power consumption.
- Ability to withstand in harsh environmental conditions.
- Self configurability
- Self healing
- Scalability
- Availability of different OS can be configured in real time operating system.

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On literature survey, it is found that, the study of wireless sensor network is the field of interest and therefore, the researchers are undertaking the research work related to the Wireless Sensor Network(WSN). Wireless Sensor Network (WSN) [3] is fast growing field of electronics for research of applied nature. The Santosh Kumar et al developed sensor network for dying industry monitoring and control system, which is wired about PIC 16F877 and deployed to monitor various parameters[4]. The recent release of standards in the field such as IEEE 802.15.4 and Digi brought the technology out of research labs and empowered to deploy for real world applications [2]. Corke et al have developed an electronic system for applications like cattle monitoring, ground water monitoring, rainforest monitoring [5]. Chiara buratti, worked on Wireless Sensor Network (WSN) technology and its evolution [6]. In order to monitor the concentration of hydrocarbons particularly, in chemical industries a Wireless Sensor Network (WSN) based system is developed by Kane et al [7] and interpreted the results, which could support the optimization of production. Zigbee based mine safety monitoring system is developed by Rajkumar Boodu [8]. This paper presents the designing of Wireless Sensor Node designed to detect and monitor the leakage of the industrial gases. For this purpose the system is wired about PIC 18F4550 microcontroller, which has promising salient features. After comparison of various RF modules, the Zigbee module is selected and employed to transreceive the data. Zigbee technology is new technology in RF communication, which work with low power and in free Industrial, Scientific and Medical (ISM) band.

II. DEVELOPMENT Of WIRELESS SENSOR NODE For WIRELESS SENSOR NETWORK APPLICATION

Deploying on chip resources of PIC 18F4550 Microcontroller the sensor node, required for Wireless Sensor Network application, is designed. Emphasizing embedded philosophy, both hardware as well as firmware is designed for wireless sensor node for dedicated applications. The present Wireless Sensor Network is designed to recognize the leakage of the industrial gases. Emphasizing monitoring of leakage of the alcohol gas at typical industrial environment, the sensor nodes are designed. Moreover, the co-ordinator node is configured to establish proper communication with the base station.

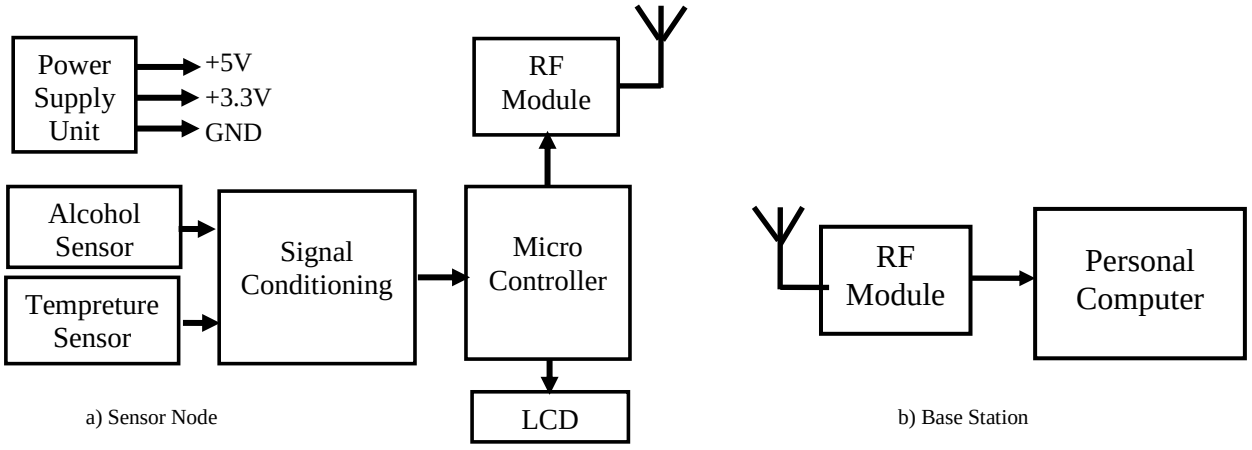

Fig. 1 Block diagram of the system

The sensors of sensor node sense physical parameter and convert it in to electrical signal either in the form of current or voltage. To amplify this low level signal, the signal conditioning stage is introduced, which follows data acquisition stage. After conditioning, the signal is fed to the analog channel of controller for digitization and further processing. After successful processing the same data is transmitted towards the base station through smart RF module.

The details regarding electronic part of the design are presented through block diagram, shown in figure 1. Moreover, the figure 2 depicts the schematic of electronic circuit of the present sensor node. On inspection figure 2, it is found that, the hardware of the system encompasses following sections.

- The Microcontroller PIC 18F4550
- Sensor Unit
- Signal Conditioning Circuit
- The Display Module
- RF Module

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The microcontroller PIC 18F4550

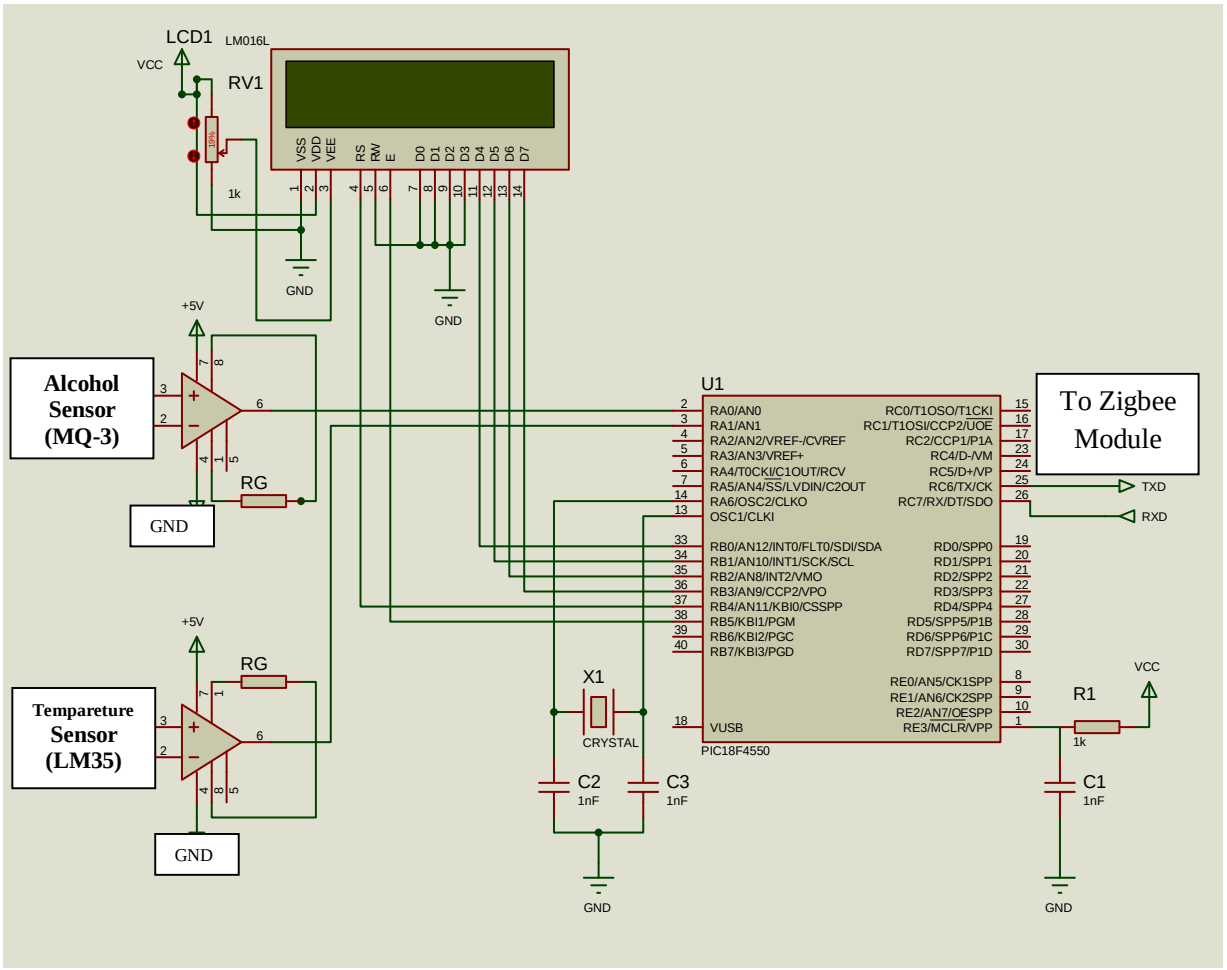

Fig. 2 Circuit schematic of the single sensor node.

The sensor node is wired about the microcontroller 18F4550, from PIC family. Based on AVR atmega8L, the Wireless Sensor Node is designed by Pawar et al [9]. This node is tiny node and consumes low power. However, the limited resources of this microcontroller exhibit constraints on the hardware design and its implementation as well. Deploying smart features of AVR ATmega128L, the designing of sensor motes is reported by many researchers. However, the reports on use of microcontroller from PIC families are rather rare. Moreover, the PIC18F4550 is having promising on chip resources [10], deploying which one can design the sensor node of dramatic features. Figure 3 describes the pin description of microcontroller 18F4550. This microcontroller is having smart on chip resources.

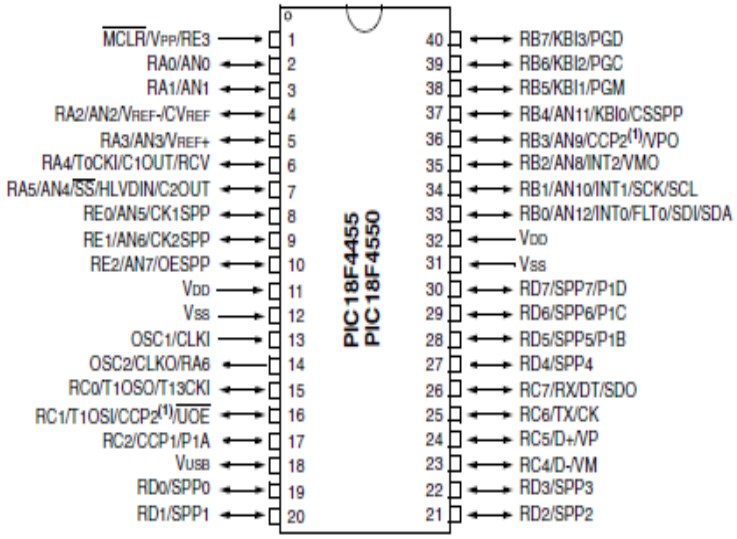

Fig. 3 PIN description of PIC 18F4550

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On chip analog to digital convertor (ADC) [11] significantly helps to improve the performance of PIC 18F4550. It has 13 analog input channels, with 10 bit resolution. The higher resolution analog to digital convertor provide a small step size ($Vref/2^n$-1) [10]. However, control of step size is possible with the help of configuration of reference Voltage (Vref.). Moreover, many researchers worked on microcontrollers like AVR, PIC 16Fxx series, which have only 8 analog channels, that offers limitations for large number of signal interfacing [12]. To avoid these drawbacks, the system is designed with PIC 18F4550. This microcontroller has advanced feature of Enhanced Universal Synchronous Asynchronous Receiver Transmitter (EUSART) [10], which exhibit auto baud rate detection and calibration. It is supported only in asynchronous mode. The automatic baud rate measurement sequence begins as start bit is received and auto baud rate detection bit (ABDEN) is set. In this mode internal baud rate generation is used as counter to select the bit period of incoming serial bit stream, the calculation is self-averaging. After a Start bit, the baud rate register (SPBRG) begins counting up, using the preselected clock source on the first rising edge of RX. After eight bits on the RX pin, or the fifth rising edge, the proper baud rate period is presented in the baud rate register. This Enhanced Universal Synchronous Asynchronous Receiver Transmitter (EUSART) [11] module ensures the full duplex mode of Serial Communication. Normally, other microcontrollers have UART which operates in half duplex mode. The EUSART can also be configured as a half duplex synchronous system that can communicate with peripheral devices, such as analog to digital convertor (ADC) or digital to analog convertor (DAC) integrated circuits, serial EEPROMs, etc. The Enhanced Universal Synchronous Asynchronous Receiver Transmitter (EUSART) module implements additional features, including automatic baud rate detection and calibration, automatic wake-up on Sync Break reception and 12-bit Break character transmit. This feature is actually helpful for present design. To interface with external peripherals, 35 general purpose input output lines are available with PIC 18F4550. All input output lines are packetized in five ports, as PORTA to PORT E. Each port pin, source and sink 25mA current, multiplexed with alternate function.

On extensive study of architecture of PIC 18F4550, it is found that this microcontroller has rich memory section. The microcontroller PIC 16F877A has on chip program memory. However, it needs 13.5 Voltage as programming voltage [13]. Therefore, the PIC 16F877A requires to separate power supply. It unnecessary increases the hardware complexity and hence the cost as well. Moreover, for programming of 16F877A a typical programmer is also needed. However, the microcontroller 18F4550 is equipped with 32Kbyte enhanced flash programmable memory for which only +5V programming power supply is sufficient. Moreover, the flash SRAM realizes the harvard structure. In addition to this, the 18F4550 also comprises the memory block associated with USB interfaces.

From these salient features, it is found that the microcontroller 18F4550 is mostly suitable for present embedded design. In addition to the input output and memory facilities, configuration analog to digital conversion and serial communication is emphasized.

To control on chip analog to digital convertor (ADC) of PIC 18F4550, the analog to digital convertor control registers (ADCON 0, ADCON 1, ADCN 2) are configured in software. These registers help to configure on chip analog to digital convertor (ADC). The ADCON 0 is configured for ADC free running mode and desired channel selection. To reduce Power consumption of PIC 18F4550, the analog to digital convertor features are turned off when the microcontroller is powered on. Therefore, analog to digital convertor must be enabled during its access. ADCON 1 registers used to configure internal or external reference voltage selection. The clock source selection is done by configuring bits of ADCON 2 register. The analog to digital convertor has a unique feature of being able to operate while the device is in Sleep mode [10]. To operate in Sleep, the analog to digital convertor clock must be derived from the analog to digital convertor internal RC oscillator. The analog to digital convertor acquisition time selection for the analog to digital convertor specified accuracy. The analog to digital convertor 10 bit result is in analog to digital convertor result register (ADRESH: ADRESL) which is configured for right justification.

Fig. 4 Temperature Sensor LM35

A. Sensor Unit

Present embedded system is designed to sense environmental parameters, temperature and leakage of the gas, alcohol in particular. To enhance the reliability of the system significantly, the sensors of promising features must be employed. On literature survey, it is found that the monolithic temperature sensor LM35 and alcohol gas sensor MQ-3 from Figaro are having good characteristics [14] and are suitable for present system.

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The LM35 [Figure 4] is a precision integrated circuit temperature sensor, with an output voltage linearly proportional to the temperature in degree centigrade. The LM35 is used for wide temperature range from -55°C to +150°C. The device is used with single power supplies and operates with low power supply range 4V to 5V. Hence, it is suitable to interface with microcontroller with on board regulated supply voltage and suitable signal conditioning and data acquisition circuits. It minimizes major part of the hardware design. Therefore, it is an attractive alternative for many temperature measurement systems.

The salient features of LM35 are;

- Calibrated Directly in degree Celsius
- Linear + 10 mV/°C Scale Factor
- 0.5°C Ensured Accuracy (at +25°C)
- Rated for Full −55°C to +150°C Range
- Suitable for Remote Applications
- Low Cost Due to Wafer-Level Trimming
- Less than 60-µA Current Drain
- Low Self-Heating, 0.08°C in Still Air
- Low Impedance Output, 0.1 W for 1 mA Load.

As mentioned earlier, the second objective of the work is to design an embedded system to monitor alcohol gas spread due to industrial process, in to air. It is found that the sensor MQ-3 is suitable for detecting the presence of alcohol gas in the air. The sensitive material of MQ-3 gas sensor is SnO_2. It has lower conductivity in clear air. When alcohol gas exists, the conductivity of sensor increases along with the increase in the gas concentration. Figure 5 shows MO-3 Sensor modules.

Fig. 5 MQ-3 Alcohol sensor

The salient features of MQ-3 are as follows:

- Good sensitivity to alcohol gas
- Long life and low cost
- Simple drive circuit

Thus the sensors, temperature sensor, LM35 and Alcohol sensor, MQ-3 are deployed and according to characteristic of these sensors the signal conditioning circuit is designed and wired.

B. Signal Conditioning Circuit

The signals extracted from the sensors, temperature sensor (LM35) and Alcohol sensor (MQ-3) are not suitable for feeding it to the data acquisition [15] system directly. Therefore, the signal conditioning circuit is developed using Op Amp of TLV series and implemented as shown in figure 2. The Op Amp has pairs of input channels and respective output channels operate on low power supply range typically 1.8v to 3.6 volt. The promising features of this operational amplifier suggest its suitability for dedicated application. The output of signal conditioner is fed to input of on chip analog to digital convertor (ADC) lines of the microcontroller PIC 18F4550 input.

C. The Display Module

To ensure digital real out the Liquid Crystal Display (LCD) module of Hitachi Corporation [Figure 6] is employed. It is composed of 2x16 line Liquid Crystal Display. In present system, LCD is configured in 4 bit mode. The circuit configuration is depicted in figure 2.

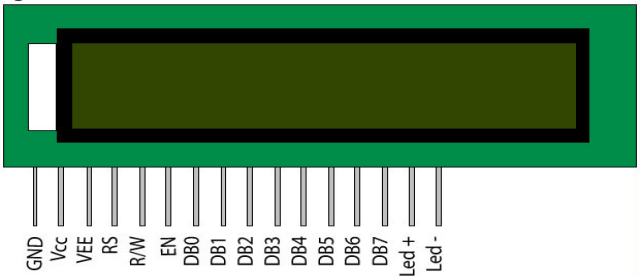

Fig. 6 LCD Pin diagram

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D. RF Module

The major objective of the present work is design the wireless sensor node required for Wireless Sensor Network (WSN), which needs RF module. On survey of various RF modules like Bluetooth (IEEE 802.15.1), Zigbee (IEEE 802.15.4), Wi-Fi (IEEE 802.11), [16] for short range wireless communication with low power consumption, it is found that Bluetooth is intended for very low data rate communication. However, the Zigbee is designed for reliable wireless monitoring and control of the networks. Bluetooth uses Frequency Hopping Spread Spectrum (FHSS) with 79 channels and 1 MHz bandwidth, while Zigbee uses Direct Sequence Spread Spectrum (DSSS) With 16 channels and 2MHz bandwidth. The major advantage of Zigbee over Bluetooth and Wi-Fi is its support up to 6500 nodes in network, and multi hopping technique.

Fig.7: Zigbee module

The Zigbee, as shown in Figure 7, is a wireless communication module [17] launched by Digi corporation and it is built to support the 802.15.4 standard. There are two versions of the Zigbee modules; 802.15.4 (DigiMesh 2.4) and ZB ZigBee. The difference is that the ZB modules are compatible with normal ZigBee networks, whereas the DigiMesh is a proprietary mesh solution. Each module comes in 2 versions: XBee and XBee-Pro. The XBee-Pro modules ensures more powerful radio, for long range.

Zigbee module designed for extremely low cost than other RF models and it is easy to deploy. It consumes very low power due to sleep mode and operates on low power supply typically 2.8V to 3.3V, chargeable batteries. Zigbee can cover wide area to be monitored. Based on multihoping the outdoor range may be enhanced.

Salient Features of Zigbee modules are:

- Power output: 1 mW (+0 dBm)
- Indoor/Urban range: Up to 90 m.
- Outdoor/RF line-of-sight range: Up to 1.6Km)
- RF data rate: 250 Kbps
- Interface data rate: Up to 115.2 Kbps
- Operating frequency: 2.4 GHz
- Receiver sensitivity: -92 dBm

III. DEVELOPMENT of SOFTWARE for WIRELESS SENSOR NODE

For proper synchronization of operation of the system, a firmware was developed in embedded C in CCS PIC IDE. Custom Computer Service (CCS) PIC Integrated Development Environment (IDE) is an integrated toolset for development of embedded application employing microchip's PIC microcontroller [10]. After successful development, the IDE produce HEX file. The HEX file is embedded in to the PIC 18F4550 microcontroller using smart programmer IDE, PICpgm. The PICpgm supports JDM programming circuit and simple 3 register programming circuit [18]. The CCS also support JDM programming circuit for on chip PIC programming, but it is complex circuit than 3 register programming circuit implemented for present system. When the device is powered up, the initialization part of the software configures various on chip peripherals such as analog to digital convector (ADC), Enhanced Universal Asynchronous Receiver Transmitter (EUART), timers and interrupts etc., and initializes externally interfaced LCD and other devices. On initialization, the digital data of respective sensor is read and processed according to firmware. The parameter values are displayed at local area on LCD and transmitted to base station through Tx buffer and Zigbee RF module.

IV. RESULTS and DISCUSSION

The main aim of the research work is to develop an industrial environment monitoring system. Present paper describes monitoring of two parameters, temperature and concentration of alcohol gas as well. The system is developed and implemented for monitoring of industrial environment to ensure real application. Before implementation, the system is exposed to the process of calibration and standardization, which helps to obtain information about temperature and alcohol gas existence in respective units. The analog part of the hardware provides the emf, in millvolt, in proportion with value of actual variables, the temperature and alcohol gas concentration. Therefore, it is essential to convert these emfs in to degree centigrade for temperature and relative units for alcohol gas. For calibration to the temperature scale, the sensor of the node is exposed to the controlled environment, whose temperature is controlled from 25^{o}C to 95^{o}C, the range of temperature sensor LM35 [19], and observed emf is recorded. These observed emf values (V_T) are plotted

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against applied temperature (t) and graph is depicted in figure 8. It can be said that, the system exhibit linear response with the applied temperature. Implementation of list square fitting process to this data, results in to the expression

$$V_T = 1.086\ t - 4.048 \quad (1)$$

This expression is employed in the software to produce output in real unit, the degree Celsius.

Similarly, the system is also extended to obtain alcohol gas concentration in relative units. An emf shown by system for only alcohol gas (V_g) is recorded. The emf (V_a) observed for environment, wherein alcohol gas is dissolved is also recorded. Then, concentration of alcohol gas is relatively measured in percentage

$$C=V_a/V_g)*100\% \quad (2)$$

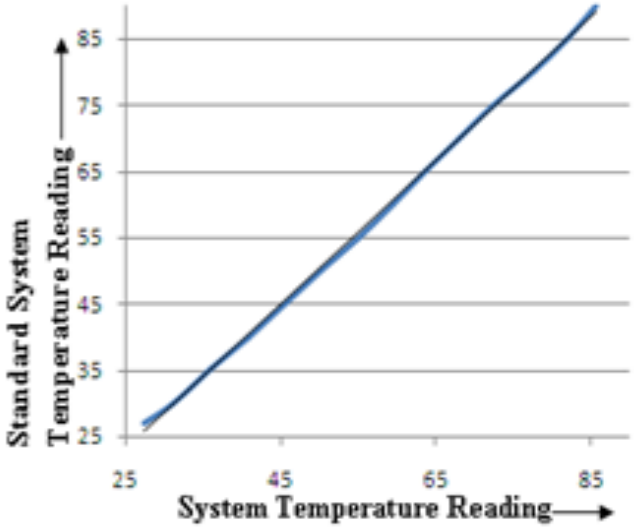

Fig. 8: Graph of temperature Shown by system vs. standard system

Thus, the present embedded system, the Wireless Sensor Node, is calibrated to standard units. The system is implemented to ensure Wireless Sensor Network application. Deploying, the Zigbee as RF module the Wireless Sensor Network is established at alcohol as well as sugar manufacturing industries. Data collected by the sensor node is routed towards the base station at which co-ordinator node is interfaced. The collected data is displayed on the monitor in real time. The alarming system is also deployed and configured to desired set point. It actuates to alarms to ensure protection from any catastrophy.

V. CONCLUSION

Emphasizing measurement of temperature and concentration of alcohol gas the sensor node and hence Wireless Sensor Network is successfully designed and implemented for the purpose for which it has been designed. On inspection of the performance it can be concluded that the present system is reliable and precisely provide the data of two parameters in real time.

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