DEVELOPMENT AND IMPLEMENTATION OF ARM MICROCONTROLLER BASED CO GAS MONITORING SYSTEM

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ABSTRACT:
An attempt is made to develop a CO gas monitoring system which is portable, cheap and easy to implement. The hardware system development is divided in six major parts, viz. the gas sensor, signal conditioning circuit, ARM microcontroller on-board system, display system and Zigbee network. To detect CO gas, metal oxide sensor (MQ7) is used. When CO comes in contact with the sensor element it lowers its electrical resistance. The ARM LPC2148 microcontroller is used for this portable gas monitoring system. The software for this is developed using Embedded C and Keil cross compiler is used to convert to machine code before downloaded to ARM microcontroller. The program is burned using Extreme Burner for ARM. The developed system is simple and small in size. It is found that the gas concentration indicated by the developed system is a linear function of CO gas concentration in the test chamber and the output is in good agreement with the actual gas concentration. This indicates that the developed system works with great accuracy and reliability. The system has been successfully employed to monitor the concentration of CO gas released in a chemical reaction under controlled conditions in the laboratory. The system can be modified for sensing more than one gas.

KEY WORDS: *ARM microcontroller, CO gas monitoring, Zigbee*

I. INTRODUCTION

Today gas sensor technology requires continuous device miniaturization and low power consumption at normal conditions. The air pollution is continuously increasing and the toxic gases have to be monitored; such that increase in the normal level of them could be known and proper precaution measures can be taken. The design of the instrument based on array of gas sensors used for detection of various gases is helpful for pollution control board, hospitals, restaurant, malls, schools, colleges and various industries for monitoring and safety purpose. Among the various gases, CO is toxic gas, acting by reaction with hemoglobin and reducing its capacity for oxygen transport in the blood and thus it is very essential to monitor the CO gas concentration in the environment [1]. Wireless sensor network is showing wide spectrum of applications in various sectors. It combines sensing, computation and communication also. Majority of the applications of the WSN lies in information sensing, real time tracking, monitoring of the various physical parameters of industrial, environmental, health, automobile etc sectors [2-8]. Raju et al have reported about the pollution monitoring system using wireless sensor network. Chavan et al have reported about the application of wireless sensor network to monitor the environmental parameters of polyhouse. Sutar developed a wireless sensor node for water quality monitoring in intensive fish culture. Zigbee based mine safety monitoring system has been discussed by Boddu et al.
Mahfuz reviewed the field of Wireless Sensor Network and suggested its suitability for environmental protection [9]. They reported features of both Zigbee as well as Bluetooth technologies. Zigbee

technology supports IEEE 802.15.4 protocol and operates in the frequency of 2.4 GHZ, ISM band. The Zigbee technology is playing vital role in establishment of WSN for dedicated applications. Many researchers investigated the sensor network and reported its suitability for environmental monitoring and control [10-16]. Pande et al have reported about the AVR based CO monitoring system for the vehicle pollution monitoring. Zigbee based environment monitoring and controlling the gas plant using ARM has been reported by Pethkar et al. The sensor senses environmental parameters and sends the data to a monitoring station through which one can access the information for further use. It consumes very low power. Therefore, it helps to overcome the drawback of high power requirement of wired sensor network. Presently, there are two types of technologies used for the sensor network *viz* Zigbee and Bluetooth. On extensive study of characteristics of Zigbee and Bluetooth technology, it is found that Zigbee technology is mostly reliable and suitable for indoor as well as outdoor sensor network. It provides a transmission speed typically 250 kbps over a range of 10m to 100m [6]. Looking to this, an attempt is made to develop a CO gas monitoring system which is portable, cheap and easy to implement. The hardware system development is divided in six major parts, viz. the gas sensor, signal conditioning circuit, ARM microcontroller on-board system, display system and Zigbee network. A metal oxide sensor (MQ7) is used to detect CO gas. To pick up this signal an instrumentation amplifier AD620 with unit gain is employed. The system is developed about an advanced microcontroller ARM LPC2148, which has promising on chip resources. The software for this is developed using Embedded C and Keil cross compiler is used to convert to machine code before downloaded to ARM microcontroller. The results of design and implementation are reported and explained adequately.

II. THE HARDWARE

With the view to develop sophisticated electronic instrument for portable pollution monitoring applications it is proposed to design the sensor interface module system. The hardware of the typical sensor system and its base station are shown in Fig. 1(a) and Fig.1 (b) respectively.

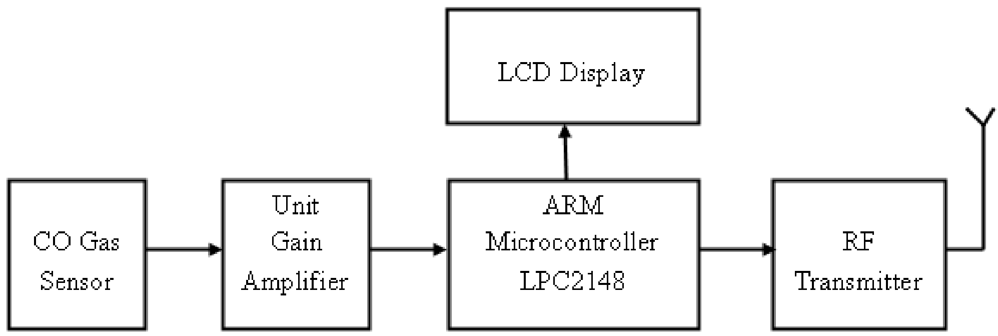

Fig. 1(a) Block diagram of gas monitoring system

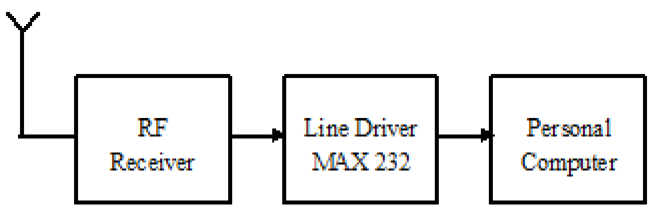

Fig. 1(b) Block diagram of gas monitoring system base station

To design an embedded system the first an important step is hardware selection. The hardware components should be chosen carefully to obtain high accuracy with minimum hardware and cost. Fig. 2(a, b) show the schematics of circuit of an embedded gas monitoring system. The hardware system development is divided in six major parts, viz. the gas sensor, signal conditioning circuit, ARM microcontroller on-board system, display system, Zigbee network and power supply. Provision is also made to interface the unit to a personal computer through serial port for system programming of ARM microcontroller as per requirement.

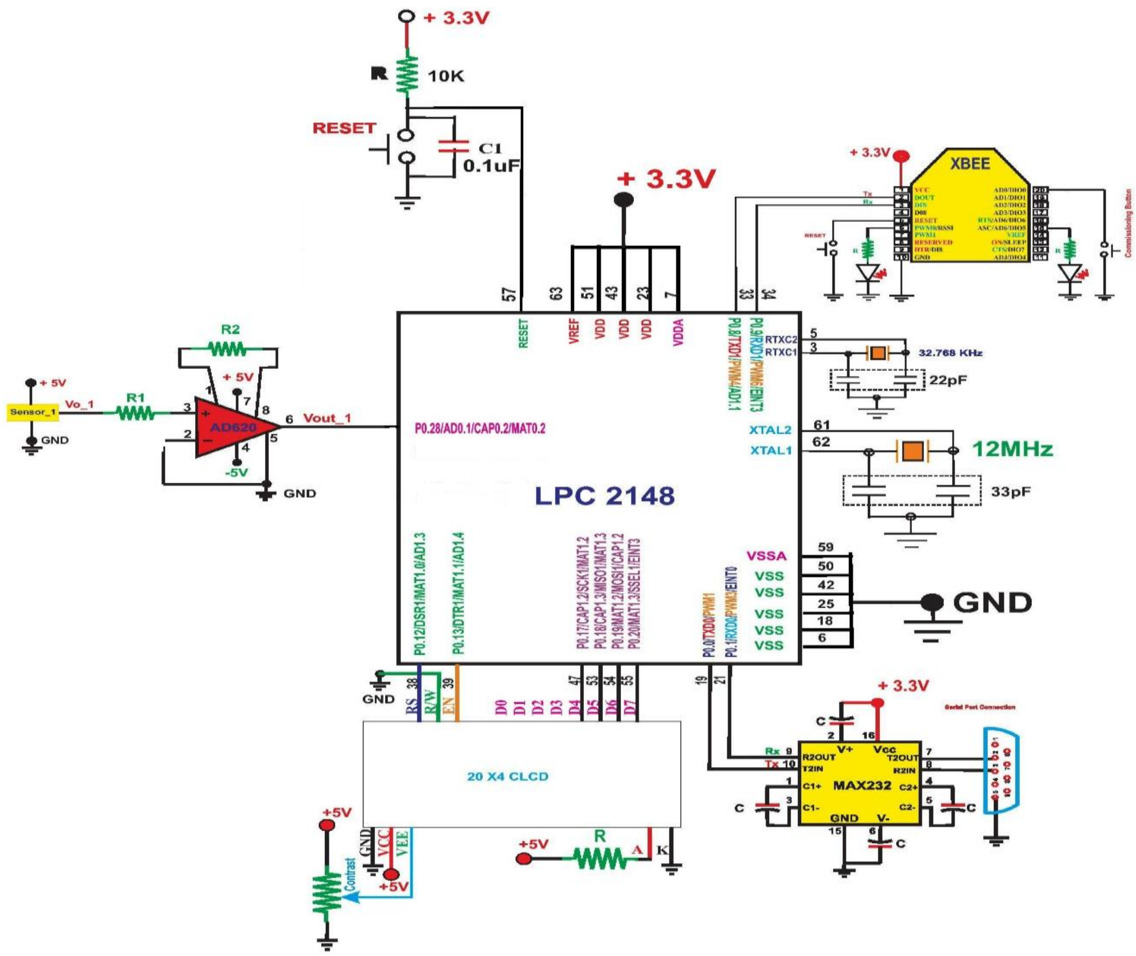

Fig. 2(a): The schematics of the circuit of gas monitoring system

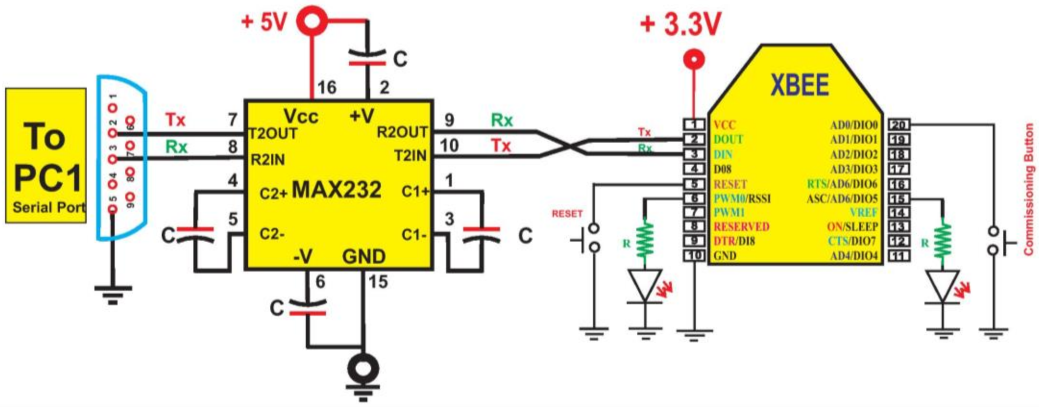

Fig. 2(b): Schematic of the base station circuit

A. Selection of Sensor:

Gas sensor is a device that is normally made up of metal oxides that senses the gas molecules. It sends electrical signals as the output which is proportional to the gas concentration. Selection of a sensor is of prime importance as it decides the overall performance of the pollution monitoring system. To detect CO gas generally SnO_2 gas sensor is used. The SnO_2 gas sensor has high sensitivity and selectivity towards CO gas. In the present study, a commercially available SnO_2 gas sensor (MQ7) is used. Fig 3 displays the photograph of gas sensor MQ7. The resistivity of this sensor depends on the concentration of the gas and its resistance varies from 2k-20k ohms. The mechanism of gas sensing is based on the conductance modulation as depicted by Suyuti et al [15]. The detecting range of this sensor is 20 ppm – 2000 ppm of carbon monoxide. The output of sensor changes linearly with the CO gas concentration in the specified range. One special property of this sensor is that the heater coil is given pulsating power supply. For 60 sec the heater is given 5 volt supply and for the next 90 sec it is given 1.4 volt supply [17]. Due to this property the power consumption of the system reduces.

Fig 3 CO gas sensor MQ7

B. Signal Conditioning:

A simple electronic circuit is used to convert the changes in resistance of the gas. The sensor output is converted to analog voltage by using voltage divider network. To pick up this signal an instrumentation amplifier AD620 with unit gain is employed. This amplifier is exhibiting very high input impedance, which could really help to isolate the sensor from remaining analog part of the hardware [18]. It is found that without any exposure to CO gas the gas sensor (MQ7) produces the dc output voltage 700 mV. This voltage is the offset voltage and therefore it is essential to compensate this offset voltage. The compensating voltage, equal in magnitude to that of offset voltage, is subtracted so that the offset voltage will be compensated. For the designing of data acquisition system, generally it requires the blocks such as multiplexer, ADC etc. However, present embedded system is developed about the advanced microcontroller ARM LPC2148, which has promising on chip resources. The analog output of Unity gain amplifier is then digitized and processed by ARM Microcontroller (LPC 2148).

C. ARM Microcontroller:

The microcontroller used in the present study is the LPC2148. Deploying LPC2148 series for the designing of an embedded system for dedicated application is reported by various investigators [19-21]. Fig.4 depicts the pin configuration of microcontroller LPC2148.

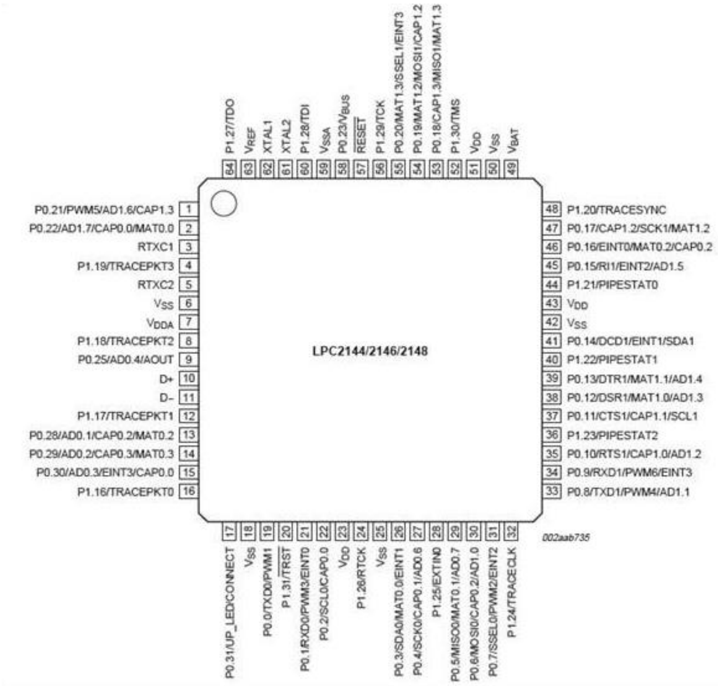

Fig. 4: Pin configuration of LPC2148

The LPC2148 are based on a 16/32 bit ARM7TDMI-S CPU with real time emulation and embedded trace support, together with 128/512 kilobytes (KB) of embedded high speed flash memory. A 128 bit wide memory interface and unique accelerator architecture enable 32 bit code execution at maximum clock rate. For critical code size applications, the alternative 16 bit thumb mode reduces code by more than 305 with minimal performance penalty with their compact 64 pin package, low power consumption, various 32 bit timers,4 channel 10 bit ADC,USB port, PWM channels and 46 GPIO lines with up to 9 external interrupt pins [6].

Due to tiny size and low power consumption, LPC2148 are ideal for applications where miniaturization is a key requirement. It has attractive features and is suitable for a wide range of applications. The important features are [22]:

- 8 to 40 kB of on-chip static RAM and 32 to 512 kB of on-chip flash program memory.
- 128 bit wide interface/accelerator enables high speed 60 MHz operation.
- It has In-System/In-Application Programming (ISP/IAP) via on-chip boot-loader software. Single flash sector or full chip erase in 400 ms and programming of 256 bytes in 1ms.
- Embedded ICE RT and Embedded Trace interfaces offer real-time debugging with the on-chip Real Monitor software and high speed tracing of instruction execution.
- Two 10-bit A/D converters provide a total of 6/14analog inputs, with conversion times as low as 2.44 μs per channel.
- Single 10-bit D/A converter provide variable analog output.
- Two 32-bit timers/external event counters (with four capture and four compare channels each), PWM unit (six outputs) and watchdog.
- Low power real-time clock with independent power and dedicated 32 kHz clock input.

D. The Display Unit:

Liquid Crystal Display (LCD) is used to display the status of the process. Nowadays a 16x2 alphanumeric LCD is most widely used module of LCD. Its low cost, large number of display characters and easy programming feature makes them suitable in number of applications. It has two types of inbuilt registers, viz. Command Register and Data Register. The Command register is used to insert a special command into the LCD while Data register is used to insert a data into the LCD. Command is a special set of data which is used to give the internal command to LCD like Clear screen, move to line 1 character 1, setting up the cursor etc.

E. Zigbee:

The data is also sent to main monitoring system (PC) for further processing and analysis using Zigbee network. The Zigbee, shown in Fig. 5, is a wireless transceiver supporting the IEEE 802.15.4 protocol. By default, the Zigbee modules are configured from the factory to be a wireless serial line replacement. It can be programmed to do other functions which behave as the "wireless wire" where a level transition on an input pin of one module is sent out as the same level transition on a different module output pin.

Fig. 5 The RF module Zigbee Pro

The salient features of Zigbee are as follows [19].
Power output: 63 mW (+18 dBm) North American version
Indoor/Urban range: Up to 300 ft (90 m)
Outdoor/RF line-of-sight range: Up to 1 mile (1.6 km) RF LOS
RF data rate: 250 Kbps,
Interface data rate: Up to 115.2 Kbps
Operating frequency: 2.4 GHz
Receiver sensitivity: -100 dBm (all variants)
Power output: 2mW (+3 dBm) boost mode
The architecture of the Zigbee module is presented in Fig. 6. Data enters the module UART through the DIN (pin 3) as an asynchronous serial signal. The signal should idle high when no data is being transmitted. Each data byte consists of a start bit (low), 8 data bits (least significant bit first) and a stop bit (high). Fig. 7 illustrates the serial bit pattern frame of data passing through the module. The module UART performs tasks, such as timing and parity checking, that are needed for data communications. Serial communications depend on the two UARTs to be configured with compatible settings (baud rate, parity, start bits, stop bits, data bits) [18].

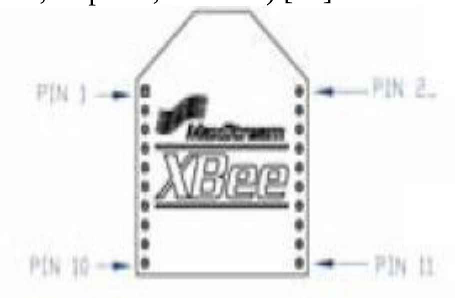

Fig. 6: Zigbee architecture

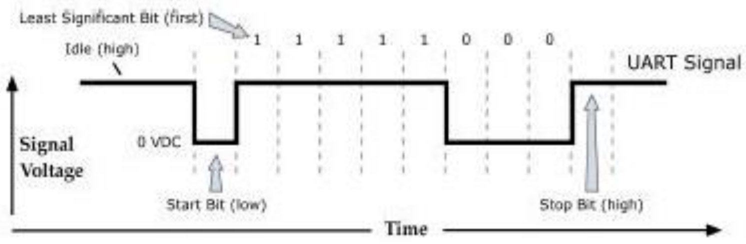

Fig. 7: Serial bit pattern frame

F) The Base Station:

As depicted in Fig 2 (b) the base station consist of the RF module Zigbee as the wireless receiver. It is serial receiver and produces the serial data. The two lines TxD and RxD are interfaced to the PC via serial port RS 232. However, it is known that RS 232 is not following TTL Logic levels. Therefore, the Max 232 is incorporated as the line driver. The parameter values which are already calibrated at the sensor node is read serially into the PC and stored for further processing and analysis.

G) Power Supply:

A separate power supply unit is employed for the sensor system module. The Regulated power supply is used to create 3.3volt for microcontroller and 5 volt for sensor circuit and signal conditioning circuit.

III. THE SOFTWARE

The work emphasizes the development of sensor array network. It is an embedded system. Therefore, for the synchronization of operations, the firmware is required. The present embedded system is based on ARM LPC2148. Therefore, Keil is employed as the IDE and firmware is developed in embedded C environment [24]. Along with the main programme the firmware comprises various modules developed for specific tasks. The Extreme Burner is used to burn the firmware and main programme in to the LPC 2148 ARM Microcontroller. Following modules (subroutines) are developed and used in the program with proper sequence.

a) Reading of the analog signal [Read data ()]
b) Analog to digital conversion [ADC (channel)]
c) Initialization of LCD [lcd_init( )]
d) Character display [lcd_display]
e) Decimal to BCD and ASCII conversion [(dec-bcd)]
f) Serial communication [ser_trans_zigbee()]
g) Parameter value display [LCD( )]
h) Configuration of LCD [LCD cmd ( )]
i) Sending data to LCD [LCD data( )]
j) Delay Function [Msdelay( )]

IV. RESULTS AND DISCUSSION

The system has been designed to detect CO gas. For calibration CO gas concentration dependent voltage was measured for various gas concentrations. The experimental arrangement for the calibration of gas monitoring system is shown in Fig. 8.

Fig.8 Experimental setup for the calibration of ARM based CO gas monitoring system

Initially, without any exposure to CO gas, the offset voltage of sensor circuit is compensated by adjusting the preset potentiometer of the compensation circuit. The sensor was then exposed to the known concentration of CO gas and corresponding voltage output was recorded as a function of gas concentration. It is found that the output voltage of AD620 is a linear function of gas concentration. This output voltage is then digitized using ARM microcontroller and displayed on LCD display. Fig.9 displays the variation between the gas concentration in the test chamber and the gas concentration indicated by the developed system. It is observed that the output is in good agreement with the actual gas concentration indicating that the developed system works with great accuracy and reliability. Thus the developed embedded system can be used to measure the concentration of CO gas.

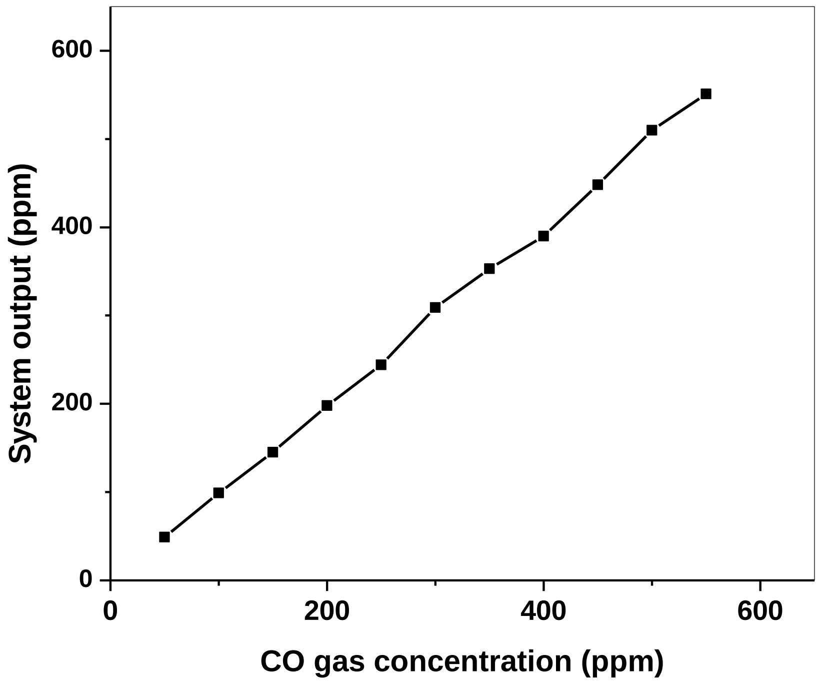

Fig. 9: Output of the system as a function of input gas concentration

To test the suitability of the developed system, it was used to measure the concentration of CO gas released in a chemical reaction carried out in the laboratory under controlled conditions. First, carbon dioxide was generated by the neutralization reactions between hydrochloric acid and calcium carbonate and then it was passed over heated charcoal to form carbon monoxide. The sensor was placed near the outlet of reaction vessel and gas concentration was recorded after every half minute. Fig. 10 shows the variation of CO gas concentration released in a chemical reaction as a function of time. Initially the gas concentration increases and then as time goes it decreases slowly. The important features of the system are: it reads the data continuously, displays on LCD display and sends to monitoring system (base station) through the ZigBee.

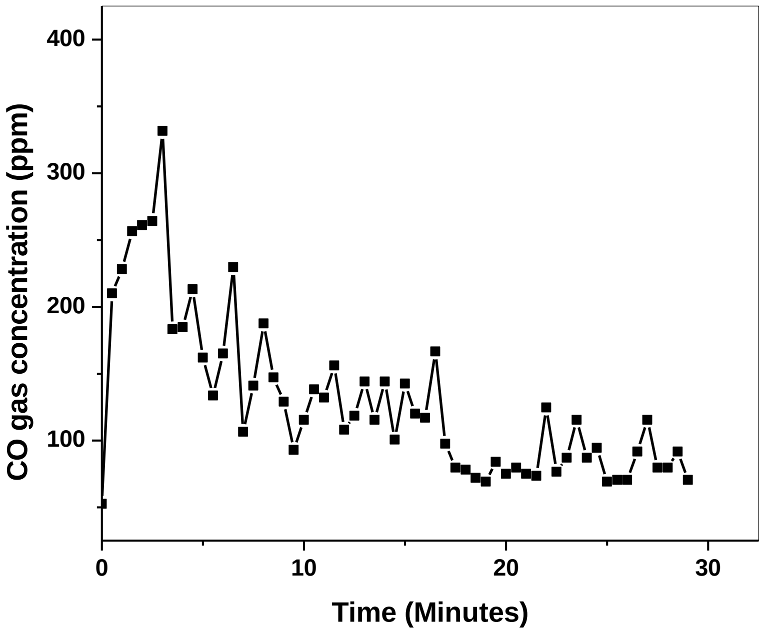

Fig. 10: Variation of CO gas concentration released in a chemical reaction

V. CONCLUSION

Employing embedded technology based on ARM7 LPC2148 microcontroller, portable system is designed and implemented for CO gas monitoring. Use of smart sensor module causes to enhance the accuracy and reliability as well. On inspection of the results, it is found that the data given by the sensor node is accurate. The RF module Zigbee operated at 2.4GHz ISM band really help for secure data transmission. The CO gas is continuously observed on the monitor of the monitoring system. Thus, any one could get the concentration of Co gas in the environment, which could be helpful for further analysis. This system provides quick response rate and works with great reliability.

VI. FUTURE SCOPE

In future, we would like to extend this work to design a monitoring system with capability to sense all toxic gases with high accuracy. Also, if the gas concentration exceeds the threshold level then an alarm can be generated immediately and an alert message can be sent to the authorized person through the GSM. The advantage of this automated detection and alerting system is that it will offer quick response time and accurate detection of an emergency and in turn leading faster resolution of the critical situation.

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