ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 2, August 2012

CAN Based Fire and Gas Safety System

G Reddappa Reddy, Neeli Karthik, P V Rajesh, Gerardine Immaculate Mary

Abstract*— *Fire and Gas system (FGS) are important tools for safeguarding process plants and production facilities that handle flammable and toxic materials. In general, a conventional fire and gas system has several shortcomings, such as weakness to noise and false alarms. Hence, in order to overcome these shortcomings, Controller Area Network (CAN) based fire and gas safety system is implemented. Simulation of system is designed and carried out in CANoe v7.6. The system has been implemented using Freescale PowerPC MPC5567 with CAN interface. In this implementation there are two modules, fire detection system and air quality monitoring system.In the fire detection system three CAN nodes are used, one for controller node and other two nodes each contains both sensor and an actuator. The control node is responsible for examining the status of the fire detectors and if it receives an alarm frame it sends an extinction frame to the corresponding node to put out the fire. The sensing node sends its status to the control node and if it detects a fire, it transmits an alarm frame to the control node. Air Quality monitoring system consists of five nodes, one is controlling and monitoring node, two are sensing nodes and other two are actuator nodes. The role of control node is to send poll frames to both sensing nodes, receive status frame compare the data with fixed threshold and if data exceeds the threshold it sends alarm frames to respective actuators nodes. It also displays the range of the concentration. Sensing node receives analog values from sensor converts them to digital values and sends data to control node. Actuator nodes receives alarm frame from the control node then rotates actuator with variation in speed based on the range of concentration of gases. We have used a DC motor of 300 rpm as an actuator and MQ135 sensor for sensing the smoke and gas concentration and an LCD for displaying range of concentration of gases in air.

***Index Terms*— Alarm Frame, CAN, CAN Based Safety Applications, Control Node, Extinction Frame, Poll Frame, Sensing Node, FGS.**

I. INTRODUCTION

Fire and Gas system (FGS) are important tools for safeguarding process plants and production facilities that handle flammable and toxic materials. Fire and gas solutions alerts people in a fast, accurate and structured way, giving personnel time to decide which course of action to take. It also enables the fire and gas system to perform the required actions to protect the plant and mitigate the damages caused by hazard. Main objective of the project is to implement Fire and Gas Safety System based on Controller Area Network. Goal of the project is to sense fire and toxic gases through their respective sensors and compare the sensed values with the threshold and start the respective actuators if the sensed value exceeds threshold value. This process involves several nodes and communication between these nodes is carried through CAN (Controller Area Network) protocol. Generally, in a conventional home automation system, home equipments, such as switches, valves, or fire detectors, are directly connected to controllers for the HAVC or fire-detection systems [1], [3], [7]. However, because of the analog transmission method, which uses 4–20 mA current, conventional fire-detection systems detect a fire as occurring when the current received from a fire detector exceeds a predefined threshold. Hence, the system has disadvantages such as a weakness to noise of various forms, including impulses or short-circuits, and a lack of awareness of the actual location of a fire. Advantages of CAN based Fire and Gas safety systems are, the controller periodically examines the state of the fire and gas detectors, it can recognize a breakdown in the system, such as the failure of a fire detector or an open circuit in the transmission medium [1], [2], [8]. In addition, the number of false alarms is less than with conventional systems because analog data such as the quantity of smoke and the amount of heat measured by each fire and gas detector can be sent to the control node [1], [2], [6]. The main objectives of the fire and gas system are to protect personnel, environment, and plant (including equipment and structures). The FGS shall achieve these objectives by:

- Detecting at an early stage, the presence of flammable gas
- Detecting at an early stage, the liquid spill (LPG and LNG
- Detecting incipient fire and the presence of fire
- Providing automatic and/or manual facilities for activation of the fire system as required
- Initiating signals, both audible and visible as required, to warn of the detected hazards
- Initiating automatic shutdown of equipment and ventilation if 2 out of 2 or 2 out of 3 detections
- Initiating the exhausting system

II. CONTROLLER AREA NETWORK

Controller area network (CAN) is a serial communications protocol which efficiently supports distributed real time control with a very high level of security [5]. It is a message based protocol, designed specifically for automotive applications but now permeating into other areas such as industrial automation and medical equipment as well [1], [5]. Several automotive electronics, engine control units, sensors etc, are connected using CAN which has bitrates up to 1 Mbps and also it replaces the wiring harness which makes design simple and cost effective [4], [5]. CAN, allow the implementation of peer-to-peer and broadcast or multicast communication functions. This is made possible as CAN use Carrier Sense Multiple Access with collision detection (CSMA/CD) as its protocol. This enables every node in the network to monitor the bus for a prescribed period of inactivity before trying to send a message on the bus which is known as carrier-sense. Every node in the network has the

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 2, August 2012

same opportunity to transmit a message after the period of inactivity for multiple access purpose. Generally, there are two different standards of CAN, namely standard CAN and Extended CAN. The standard CAN (CAN 2.0A) with 11-bit identifier, could provide signaling rate from 125kbps to 1Mbps [5]. The standard was later revamped to Extended CAN (CAN 2.0B) that could support up to 29-bit identifier with a signaling rate of 1 Mbps. The standard 11-bit identifier provides 211 or 2048 different message identifiers whereas the extended version of 29-bit could support up to 229or 537 million identifiers. CAN is subdivided into three different layers:

1) The (CAN-) object layer
2) The (CAN-) transfer layer
3) The physical layer

The object layer and transfer layer comprise all services and functions of Data Link Layer defined by ISO/OSI model.
Functions of object layer:

- Finding which messages are to be transmitted
- Deciding which messages received by the transfer layer are actually to be used
- Providing an interface to the application layer related hardware.

Functions of transfer layer:

- Controlling the framing
- Performing arbitration
- Error checking
- Error signalling
- Fault confinement

Function of physical layer is the actual transfer of the bits between different nodes with respective to electrical properties.

III. IMPLEMENTATION OF THE PROJECT

A. Implementation of Air Quality Monitoring Module

The module of air quality monitoring consists of five nodes, two sensor circuits, one display module and two actuators. Two Sensing nodes are connected to two sensing circuits respectively and also to the respective Motor nodes. Control and monitoring node is connected to Sensor nodes. The five nodes above mentioned communicate through CAN protocol and connectors of any two nodes serve us as CAN bus. So we have four such buses. As CAN always broadcast messages i.e., it transmits messages to each and every node connected to the CAN bus so there is no need to take special care for connecting nodes i.e., these nodes can be connected in any order. Every CAN node has a specified range of IDs for receiving data. So though each node receives each and every frame transmitted by any node it takes data only if the frame has the ID within the range of the IDs of respective receiving CAN node. The sensing node performs the task of converting received analog values from the sensor circuit to digital values and sends the data to the control and monitoring node for the checking the concentration and displaying the range of the concentration of gas present in the air as soon as it receives poll frame from the control node. The control and monitoring node first sends poll frames to two sensing nodes requesting them the sense data. As soon as it receives the data it checks which node had sent the data frame. Then the data has to be converted to 16 bit i.e., the two bits data has to be merged together. After converting the data into 16 bit this is compared with the already set threshold and the respective range of the value is displayed on the LCD. As it continuously monitors the range of gas concentration it is also called as monitoring node. If the data exceeds the threshold value it sends alarm frame to respective motor nodes. The motor node receives ALARM FRAME from the control node which also contains data of the air concentration. So as soon as it receives alarm frame it compares with the different ranges of thresholds and it decides the speed of the motor based on the range. It then rotates motor with the respective speed. If concentration goes down the minimum threshold then motor automatically stops.

The sensor module consists of two sensing circuits of MQ135 gas sensor each. This gas sensor has high sensitivity to Ammonia, Sulfide and Benzene steam, also sensitive to smoke. The motor node gets the alarm frame from the control node and stores the received data in respective CAN buffer. Now this data is compared with the different ranges of thresholds. After decision is made it makes the motor to run with the respective speeds. The sensing node collects the sensed analogue values from the output of the sensor circuit and converts them to digital hexadecimal values with the inbuilt ADC. Then it checks for the poll frame from the control node. As soon as it receives the poll frame from the control node it starts transmitting the status frame which contains the data about concentration of gases. The control and monitoring node receives status frame from both the sensing nodes. It then compares the data with the threshold value that has been set. If the value is less than threshold then it displays "< *threshold*" and if it is ">*threshold*" value it checks for the range of the value and then it displays the respective range. If the value is greater 1 gives the block diagram of Air Quality Monitoring System and it gives an idea of various nodes present in the setup.

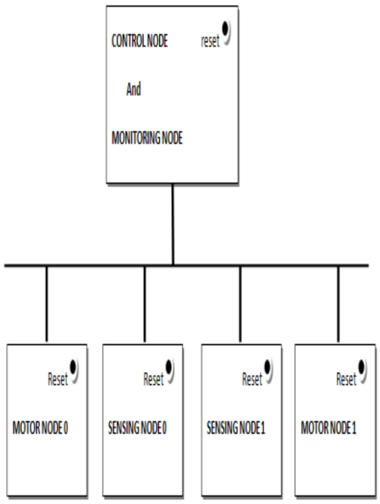

Fig. 1: Block diagram of Air Quality Monitoring System

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 2, August 2012

B. *Implementation of Fire Detection Module*

In a CAN based fire detection system three CAN nodes are used, one for controller node and other two nodes each contains both sensor and an actuator. Block diagram of the system can be seen in Fig.2.All three nodes are connected through simple connectors which acts as CAN bus. The transmission speed of CAN is set to 1 Mbps. The sensor used is MQ-135 which is sensitive to smoke. FlexDevel board, which has MPC5567 controller, is used as CAN node and DC motor acts as an actuator. The nodes can be programmed by using eclipse IDE. The control node is based on MPC5567 microcontroller. The PWM output of this node is fed as input to the amplifier circuit. This circuit with an amplification factor of two amplifies the PWM signal. This amplified signal is given as an input to the speaker. The Amplifier used is LM-741. The sensing node is connected to sensor circuit. The signal from this circuit is fed to the analog pin of the board. A DC motor, which acts as an actuator, is connected to this node. The analog values which are converted to digital can be viewed in a PC through a HyperTerminal. All three nodes are connected through simple connectors which acts as CAN bus. Each FlexDevel has two CAN connectors X800 CAN A and X810 CAN B. In turn, each connector has two interfaces. Either of the two interfaces can be used to connect to the CAN bus. CAN connector X800 is utilized in the project. As shown in Fig.4 sensor MQ-135 has six pins, out of which four pins are used to fetch signals and other two are used for providing heating current. Two pins are named A, two pins B and the others as H. Either of the two pins H is connected to V_{cc} and other pin is connected to ground. One of the pin A is connected to V_{cc} and pin B is used to collect the output. This can be done vice versa. The output pin of the sensor is fed to one of the eight analog input channels of the sensor node. The ninth analog pin is grounded.

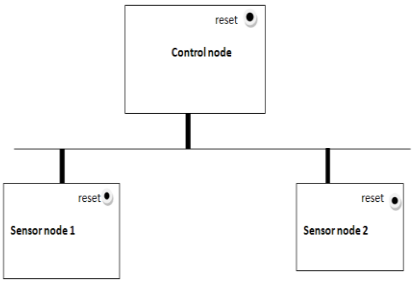

Fig. 2: Block diagram of Fire Detection System

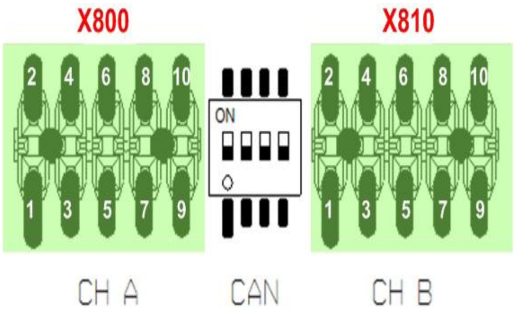

Fig. 3: CAN Interface

The two CAN connectors, X800 CAN A and X810 CAN B, as mentioned earlier can be seen in Fig.3.Two connecting wires can be connected to each connector. Each can connecting wire used 5pins of connector. The switches in the center are used to activate the connectors.

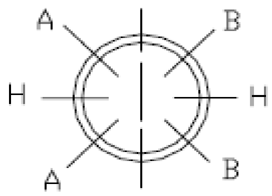

Fig. 4: MQ135 Pin Configuration

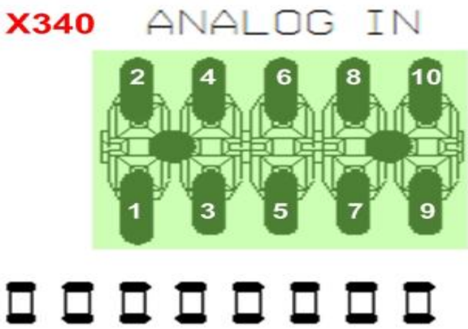

Fig. 5: Analog Input Configurations

Fig.5 shows the analog input pin configuration. Of the ten pins shown in the figure pins 1-8 are used to feed analog signals to ADC. Pin 9 is grounded and 10 is connected to V_{cc}. As in Fig.6FlexDevel has Two H Bridges, X560 and X570, to interface with motor. An external power supply of 12 V DC is to be supplied to the double screw terminal X550 mounted on the board. It has to be ensured that first power supply of the board is on and then the motor supply is on.

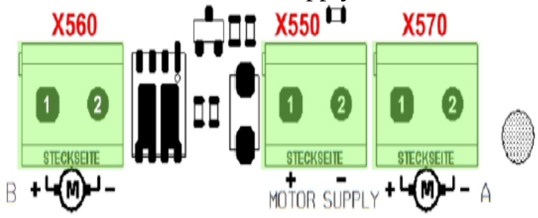

Fig. 6: DC Motor Interfaces

The PWM output pin configuration is shown in Fig.7.Here PWM output from any of the 1-8 pins is fed to the amplifier circuit. The ninth pin of the PWM is grounded. The amplifier amplifies the PWM signal and it is given as an input to the speaker.

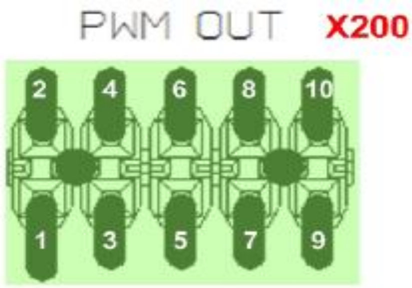

Fig. 7: Speaker Interface

In fire detection system, the controller node polls each sensing node. The sensing nodes in response to the poll frame send a status frame to the control frame. If control node has not received any status frame then it indicates that there is a breakdown in that particular sensing node. Thus the control node can periodically perceive the status of a fire-detection system such as a fire detector failure or breakdown. Suppose fire has occurred in a sensing node it transmits alarm frame to the control node. Control node in response to this alarm frame sends an extinction frame to the corresponding actuator to put out the fire. If sensing node receives an extinction frame from the control node, it stops transmitting the alarm frame. Using these methods a network based fire detection system will be superior to conventional fire detection system, because the control node in this system can identify which node has detected fire using the node ID address. And the control node can periodically examine the status of the fire detector. To satisfy the real time requirements of a CAN based fire-detection system extinction frame must be transmitted earlier than other frames. Hence extinction frame must be given highest priority, next priorities to the alarm frame and status frame respectively. The poll frame has the lowest priority.

IV. SIMULATION OF CAN BUS TRAFFIC IN CANOE V7.*6*

A. Simulation of Air Quality Monitoring Module

In this system first Control Node sends poll frame (with an ID of 400) to Sensing Node 0 and with a very small delay it also sends a poll frame (with an ID of 500) to Sensing Node 1. When Sensing Node receives a poll frame its sends a status frame (with an ID of 200) to Control Node that includes ADC output as its data. Then control node compares the received data with the threshold value and sends alarm frame (with an ID of 000) to Motor Node 0 which also contains the same data received from the Sensing Node and also at the same time it also sends a poll frame (with an ID of 500) to Sensing Node 1. Now at the Motor Node it drives motor to rotate with different speeds depending on the range. The same repeats with the Sensing Node 1 with status frame ID 300 and alarm frame ID 100. This CAN bus traffic can be seen in CANoe Trace window as shown in Fig.s 8, 9 and 10 for three different cases.

CASE 1:

This is the case where Control Node sends Poll frames to sensing Node0 and Sensing Node1 with IDs 400 and 500 respectively as shown in the Fig.10. We can see IDs 400 and 500 which means these are poll frames and names sen1 means that particular frame is transmitted to Sensing Node 0 and sen2 means that particular frame is transmitted to Sensing Node 0. DLC is Data Length that is transmitted and Data is the Data that is transmitted in CAN bus

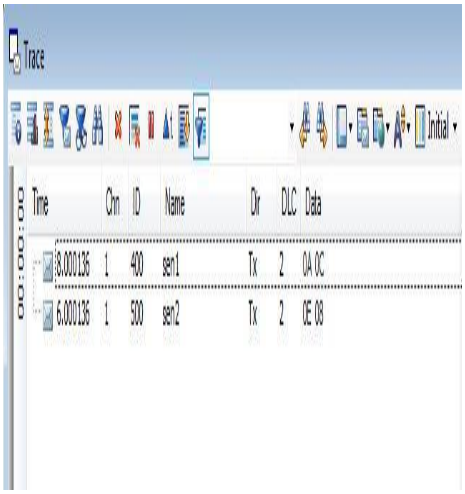

Fig. 8: showing poll frames that are transmitted for AQM

CASE 2:

This is the case where Sensing Node 0 sends status frame to the Control Node with an ID of 200 with the data 0x16FF and then Control Node sends alarm frame to motor node 0 with an ID of 000 and also poll frame to Sensing Node 1 as shown in Fig. 9.

CASE 3:

This is the case where Sensing Node 1 sends status frame to the Control Node with an ID of 300 with the data 0x16FF and then Control Node sends alarm frame to motor node 1 with an ID of 100 and also poll frame to Sensing Node 0 as shown in Fig. 10

B. Simulation of Fire Detection Module

In fire detection system control node sends poll frame of ID 600 to sending node 1. After receiving status frame of ID 400 from that sensing node, it sends another poll frame of ID 700 to sensing node 2 in order to examine the status of the fire detector. In response to this poll frame this sensing node 2 sends status frame of ID 500 to the control node. All these steps that can be seen through CAN bus, which is obtained through simulation of system in CANoe, are shown in Fig. 11

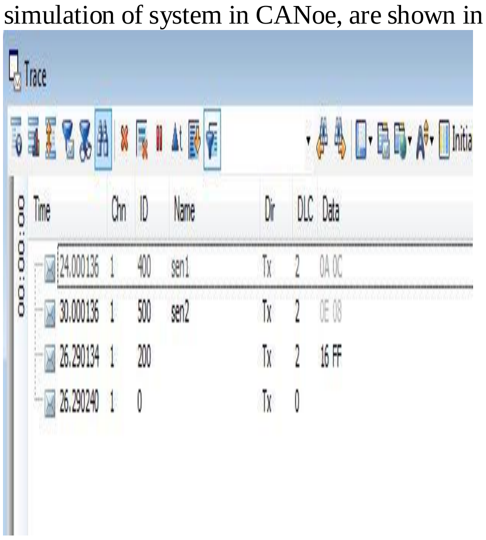

Fig. 9: Showing Status Frame from Sensing Node 0 and Alarm Frame to Motor Node 0 for AQM

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 2, August 2012

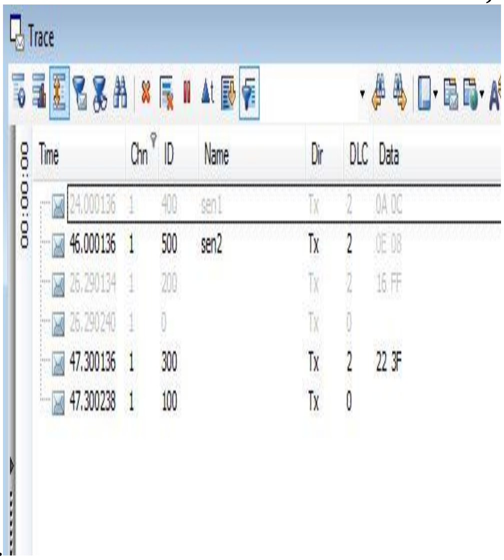

Fig. 10: Showing Status Frame from Sensing Node 1 and Alarm Frame to Motor Node 1 for AQM

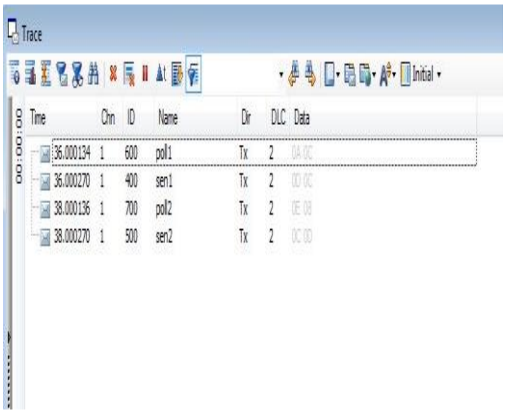

Fig. 11: Showing Poll Frames and Status Frames for FD

Now consider a case where fire has occurred in sending node 1. It sends an alarm frame of ID 200 to the control node. This node sends an extinction frame of ID 000 to the sensing node to put out the fire and it stops sending poll frame to the sensing node 1. This can be seen in Fig. 12.

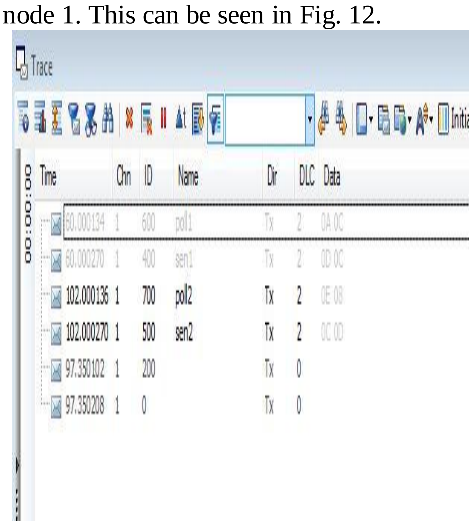

Fig. 12: Showing Alarm Frame 200 and Extinction Frame 000 for Sensing Node 1 for FD

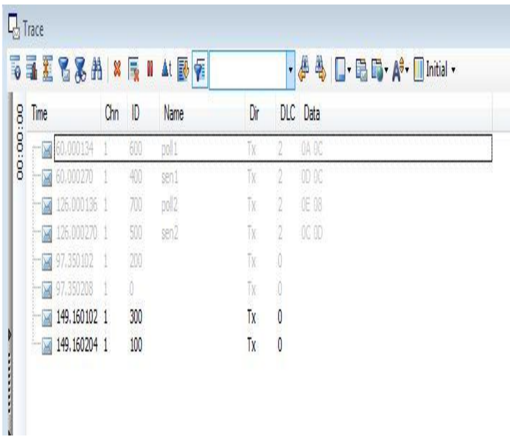

Fig. 13: Showing Alarm Frame 300 and Extinction Frame 100 for Sensing Node 2 for FD

If fire has occurred in sensing node 2, it sends an alarm frame of ID 300 to the control node. The control node in response to this frame sends an extinction frame of ID 100 to put out the fire and it stops sending poll frame to the sensing node. This can be seen in Fig. 13

V. RESULTS AND ANALYSIS

The Fire and Gas Safety system is divided into two modules one is AIR QUALITY MONITORING where mototr rotates with different speeds depending of range of concentration of gas that is being measured and an LCD display which continuously monitors the status of gas concentration. And other is FIRE DETECTION where it senses the fire and and if any fire is detected it gives an alarm through the speaker connected to the PWM out in the FlexDevel board and also in response to the fire detected it runs the motor. The Fig.s 14 and 15 show the entire experimental setup for both the modules.

Fig. 14: AIR QUALITY MONITORING Experimental Setup

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 2, August 2012

Fig. 15: FIRE DETECTION Experimental Setup

Fig. 14 shows the entire experimental setup for AIR QUALITY MONITORING.Here we can see five nodes communicating through CAN protocol, two DC motors and an LCD. We can also see a monitor which continously displays the converted ADC values which help us in fixing threshold value which is most important part of the programming Fig. 15 shows the entire setup for FIRE DETECTION. Here we can see three nodes communicating through CAN protocol, two DC motors and an alarm circuit which gives us signal with a continuous beep sound when ever fire is detected and motor atomatically rotates. The output of AIR QUALITY MONITORING where the concentration of gases in air is divided into 3 ranges and this is displayed on the LCD in the Control Node. And motor rotates with different speeds depending of the ranges as shown in Table 1

Table 1: Motor Speeds and LCD Display for Different Ranges of Gas Concentration.

RANGE	LCD DISPLAY	MOTOR SPEED
< = 0x1700	< Threshold	In off condition
0x1700 - 0x1FFF	Range 1	Speed = 30rpm
0x1FFF - 0x2400	Range 2	Speed = 75rpm
>= 0x2400	Range 3	Speed = 150rpm

VI. CONCLUSION

Using FlexDevel MPC5567 boards we have implemented CAN based fire and gas safety system. A conventional system has shortcomings such as weakness to noise and false alarms. This system has overcome all these shortcomings by using CAN as a communication protocol between the nodes. This system is basically divided into two modules. They are Fire Detection System and Air Quality Monitoring system. The Fire Detection System has three nodes, one control node and two sensing nodes. The control node examines the status of the fire detectors by polling them periodically. If fire has occurred in any of the fire detectors then it sends an extinction frame to the corresponding sensing node to run motor in order to put out the fire. Air Quality Monitoring has five nodes two Sensing nodes, one Control node and two Motor nodes. Here Control node polls two sensing nodes alternately in order to examine the status of both Sensing nodes and if any Sensing node value goes beyond the threshold then it alarms the respective Motor node with the value of Sensing node so that motor runs with different speeds based on the value of Sensing node. And the particular range is displayed on the LCD by control node. This system has been designed and simulated in CANoe v7.6 and the status of the bus can be seen in the trace window of the software. The fire detection system in this project satisfies the National Fire Protection Association (NFPA) requirements, where the fire warning response time for a fire alarm signal should be less than 90 s. In Air Quality Monitoring system as CAN protocol is message based, any node can send message to any other node. This gives tremendous flexibility to the system designer. As the system continuously monitors the status of Sensing nodes this helps us to check the functionality of Motor nodes. Since the price of a CAN microcontroller, which can be integrated into one-chip by semiconductor manufacturing companies, is low, and many CAN development tools are coming onto the market, this system, which is based on the CAN, has the advantage that the implementation of sensors or actuators is straightforward as compared to a system using an Ethernet that is the lower layer of the BACNet. However this project focuses only on the basic structure of a CAN-based fire and gas safety system. For practical application of this system, the implementation of an application layer should be studied. In addition, research into the redundancy of the communication module will be required to obtain the necessary fault-tolerance properties required in a CAN-based fire-detection system.

REFERENCES

[1] Kyung Chang Lee and Hong-Hee Lee, "Network-based fire-Detection System via Controller Area Network for Smart Home Automation", IEEE Trans. Consum. Electron, 1094 vol. 50, no. 4, pp. 1093 1100, July 2004.

[2] Minu A Pillai, Sridevi Veerasingam, Yaswanth Sai D “CAN Based Smart Sensor Network for Indoor Air Quality Monitoring”, 2010

[3] Song, S.H. Hong, and K.D. Song, “Performance analysis of BACnet-based fire detection/monitoring system in the high-rise building”, Journal of the Architectural Institute of Korea, vol. 18, no. 1, pp. 171-178, 2002.

[4] T. C. Hooi, M. Singh, Y. K. Siah, and A. R. Ahmad, “Building Low- Cost Intelligent Building Components with Controller Area Network (CAN) Bus,” Proceedings of IEEE Region 10

International Conference on Electrical and Electronic Technology, pp. 466-468, 2001.

[5] Hanxing Chen and Jun Tian, "Research on the Controller Area Network", International conference on Networking and Digital Society, pp. 251-254, 2009.

[6] O. Postolache, M. Pereira and P. Girao, "Smart Sensor Network for Air Quality Monitoring Applications", Proc. of Instrumentation and Measurement Technology Conference, pp. 537- 542, May 2005.

[7] N. Sriskanthan, F. Tan, and A. Karande, “Bluetooth based home automation system,” Microprocessor. Microsyst, vol. 26, pp. 281-289, 2002.

[8] D.T. Gottuk, M.J. Peatross, R.J. Roby, and C.L. Beyler, “Advanced Fire Detection Using Multi-Signature Alarm Algorithms,” Fire Saf. J., vol. 37, no. 4, pp. 381-394, 2002.

AUTHOR’S PROFILE

G Reddappa Reddy was born in Hindupur, Andhra Pradesh, India in 1990. He received B.tech degree in Electronics and Communication from VIT University, in 2012. He is currently pursuing M.Tech in Reliability Engineering in IIT Kharagpur. His interested areas are Embedded System Design and Communication.

Neeli Karthik was born in Nandyala, Andhra Pradesh, India in 1990. . He received B.Tech degree in Electronics and Communication from VIT University, in 2012. His interested areas are Embedded System Design and Application Developing.

P.V.Rajesh was born in Puttaparthy, Andhra Pradesh, India in 1991. He received B.Tech degree in Electronics and Communication from VIT University, in 2012. His interested areas are Networking and Embedded System Design.

Gerardine Immaculate Mary received her M.Tech degree with specialization in Wireless Communication from Pondicherry Engineering College, Pondicherry. She is now Assistant Professor (Senior), School of Electronics Engineering, Vellore Institute of Technology (VIT), Vellore. She also has over 12 years of industrial experience as computer hardware engineer. Her research areas include wireless communication in automation and vehicular environments, indoor wireless positioning and Ultra Wide-Band Technology applications. She has published several research papers in international journals and conferences.