FPGA-GSM based Gas Leakage Detection System

Arpitha .T[1], Divya Kiran, V. S.N. Sitaram Gupta and Punithavathi Duraiswamy[2]
Department of Electronic and Communication Engineering
M.S. Ramaiah University of Applied Sciences
Bangalore-58, India
[1]*arpitha9220@gmail.com*
[2]*punithavathi.ec.et@msruas.ac.in*

***Abstract*—Gas leakage is a major problem in industries, residential premises and gas powered vehicles. The leakage if not detected may lead to explosion and cause severe damages to life and environment. The conventional leakage detection system uses on-site alarms for warning. In this paper, we propose a leakage detection method in which the leakage information is also sent to first response team through wireless media. This ensures preventive actions immediately even in the absence of people on-site. The detection system uses FPGA to detect the leakage and automatically initiate a warning call through a GSM. A prototype of the gas leakage detection system has been developed and tested with LPG (Liquefied Petroleum Gas). The experimental results show that the system is able to detect the leakage in less than a minute.**

Keywords—FPGA, Sensor, GSM, UART, ADC, leakage

I. Introduction

Toxic and inflammable gases are widely used in industry, heating systems, home appliances and vehicles [1]. This includes combustible gases like propane, ethane, butane, methane, ethylene etc. Liquefied Petroleum Gas (LPG), also referred to as propane or butane are normally stored in pressurized cylinders in liquid form and vaporize at normal temperatures. A leakage can ignite and cause explosion. Therefore, the leakage detection of gases has gained more interest in recent years especially in fields of safety, industry, environment, and emission control [2]-[4]. A conventional gas leakage system uses on-site alarms as a warning to indicate the leakage [3]-[6]. The drawback of the conventional leakage system is that it becomes ineffective in the absence of first response team on-site. This may delay the preventive actions causing damage to life and environment. Therefore, there is a need for a system to detect the leakage and send the information to the first response team through wireless media. A leakage detection system that initiates a warning call or SMS will be more effective in the absence of people on-site. Moreover, the leakage warning call can be sent to fire station as well. Gas leakage detectors built with microcontrollers to detect and send information through wireless media is presented [7]. Alternatively, an FPGA can be used in the detection system to detect many toxic and combustible gases making them ideal for use in a variety of environments. FPGAs clearly have many advantages as far as the high-performance systems are concerned where smoothing filters are required to clean the sensor data [8]. In this paper, we propose a leakage detection system that uses FPGA to detect the leakage with a warning call initiating feature to the first response team. LPG is used to test the system. The paper is organized as follows. An overview of the gas leakage detection system is explained in section II. The leakage detection and call initiation in FPGA is explained in section III and section IV explains the experimental setup and the conclusion is given in section V.

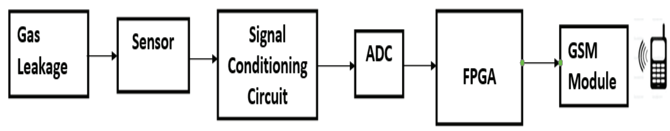

Fig.1 Overview of the gas leakage detection system

II. System Overview

An overview of the gas leakage detection system is shown in Fig.1. It consists of a sensor, signal conditioning circuit, Analog to Digital converter (ADC), FPGA and a GSM module. The sensor detects the gas leakage. Here, MQ-6 sensor is used as it is suitable for sensing LPG concentrations in air. They are also suitable for detecting iso-butane and propane. It can detect gas concentrations anywhere from 200 to 10000 ppm and has fast response time [9]. The sensor's output is an analog resistance. The change in resistance is converted into a voltage by means of a signal conditioning circuit. In this case, a Wheatstone's bridge along with an operational amplifier is used to convert the change in resistance to voltage [10]-[12]. The operational is used to linearize the bridge output. The circuit diagram of the operational amplifier based signal conditioning circuit is shown in Fig. 2. An 8-bit ADC converts the sensor analog voltage into digital. In FPGA, the data from the ADC is measured and compared with a threshold. If a leakage is detected, a decision is made to initiate a call by reading the mobile number stored in a memory and sending it to the GSM module. An Universal Asynchronous Receiver/Transmitter (UART) is used as an interface between the FPGA and GSM module for sending the data [13], [14]. The next section explains in detail the leakage detection and warning call initiation in FPGA.

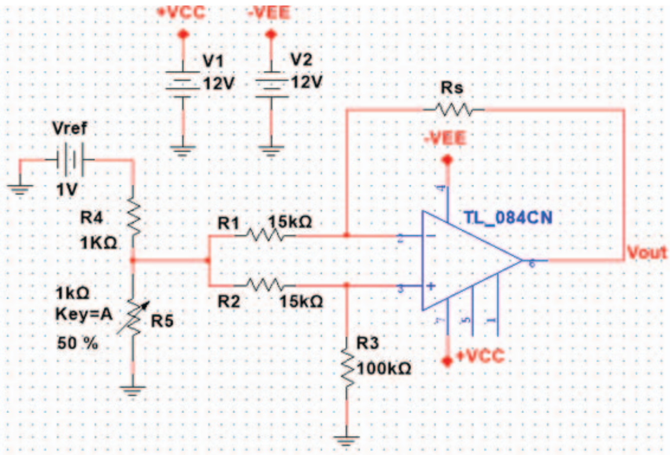

Fig.2 Signal conditioning circuit

III. Leakage Detection in FPGA and Call Initiation

The leakage detection is carried out in FPGA as shown in Fig.3. The digital input voltage to the FPGA is compared with a threshold value to detect the leakage. If the input voltage is more than the threshold, a leakage is detected and a read logic reads the mobile number stored in the memory. This number is sent to the transmit UART controller which converts the input parallel mobile number to UART bit stream by adding start and stop bits. A shift register is used to convert the parallel data to serial data and the transmitter control logic adds one stop bit and two start bits. The necessary baud rate for the UART controller is generated by means of a baud rate generator which is a clock divider circuit. Here, a baud rate of 9600 is generated from a clock frequency of 100 MHz. The output bit stream from the transmit UART is sent to the GSM module, thus initiating a warning call to the first response team.

A. FPGA- GSM Interface

An UART is used as an interface between the FPGA and GSM module for sending the data. The Attention (AT) command required for initiating a call requires only mobile number storage along with the code “ATD” whereas for a SMS, the message also needs to be stored along with the mobile number in FPGA. Therefore, it is decided to initiate a warning call rather than a SMS. Initially, both initiating a call and SMS is tested by interfacing the GSM module (SIM 300) with PC and sending AT commands from PC to the GSM module. Then, a HDL code is developed to detect and initiate the warning call for the architecture shown in Fig.3. The simulation results of the HDL code in Fig.4 shows the transmit UART transmitting the bit streams to the GSM module. Before using the HDL code in the gas leakage system, Spartan 3e FPGA board is interfaced with the GSM board to test the call initiating feature implemented in FPGA.

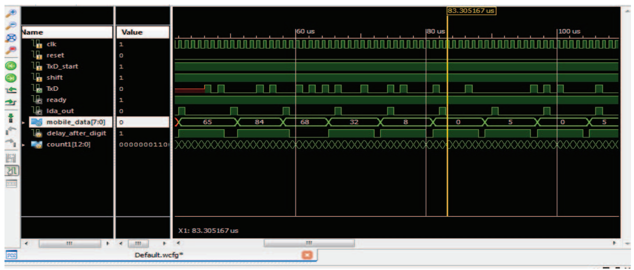

Fig.4 Simulation results of transmit UART sending the bit streams to GSM module

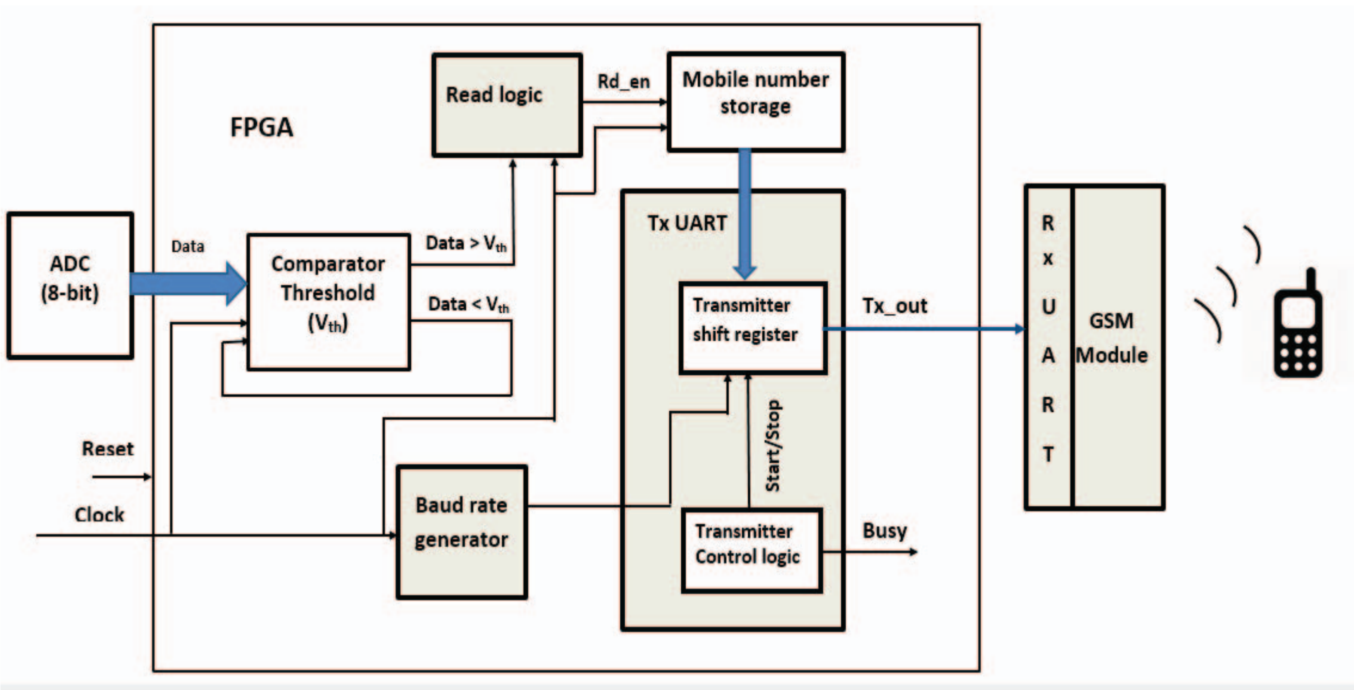

Fig.3 Leakage detection and call initiation in FPGA

IV. Experimental setup And Measurements

A. Threshold fixing

A prototype of the gas leakage system developed is shown in Fig.5. The leakage detection system requires a threshold voltage to detect the leakage. To fix the threshold voltage for comparison in FPGA, the noise voltage without gas is measured. The noise voltage measured without gas is 0.02 V. Normally, the threshold is fixed above the noise voltage. However, the smallest concentration that MQ-6 can detect is 200 ppm which corresponds to a voltage of 0.61 V. This is verified by measuring the gas concentrations. The measurement results for the gas concentrations is shown in Fig.6. Here, for testing purpose, a threshold of 0.7 V is used. This requires an injection of more than 800 ppm of LPG into the gas chamber.

B. Testing with LPG

For testing the system with LPG, the following preparations are required. First, the MQ-6 sensor requires preheating for about 24 hours. Then, the gas chamber is made free from contaminants by turning on the mixing fan for 2-3 minutes. Once these preparations are done, the MQ-6 sensor is inserted into the gas chamber by means of a probe. A 900 ppm of LPG is injected into the gas chamber. FPGA detects the leakage and initiates the warning call. It is seen within a minute of leakage; the warning call is received by the mobile phone.

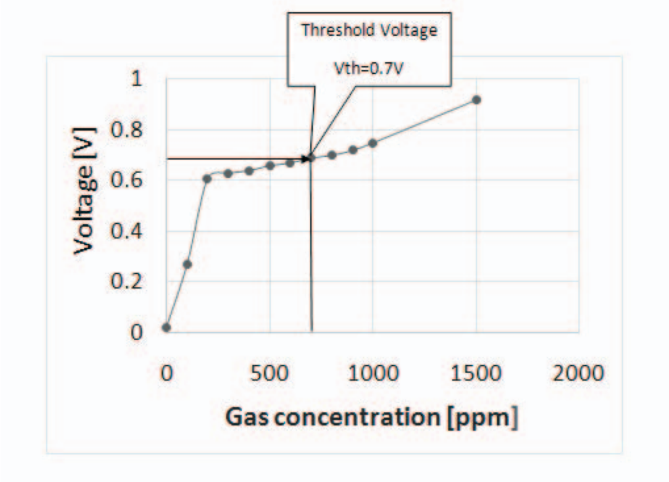

Fig.6 Gas concentration measurements

V. Conclusion

An FPGA –GSM based gas leakage detector with a warning call initiating feature to the first response team is presented. The FPGA detects the leakage and initiates a warning call through a GSM module. A prototype of the gas leakage detector has been developed and successfully tested with LPG. The detector is able to send the warning call to the mobile number stored in the system in less than a minute. The proposed leakage detection with warning call initiation can be extended to send calls/SMS to multiple people and can be directly linked to the fire station as well. Future work may include cleaning of the sensor data by averaging the collected data in FPGA. Also, multiple sensing

Fig.5. Experimental setup of the gas leakage detection system

devices can be interfaced for various applications and signal processing can be carried out in FPGA.

References

[1] A. Mandelis, and C. Christofides, "Physics, Chemistry and technology of solid state gas sensor devices," Wiley, 1999.

[2] J. Yeom *et al*., "Enhanced toxic gas detection using a MEMS preconcentrator coated with the metal organic framework absorber," *Micro Electro Mechanical Systems,. IEEE 21st International Conference on*, Tucson, AZ, 2008, pp. 232-235.

[3] P. Krishnan and D. Jackson, "Multifunctional gas detection based temperature compensation and data fusion," *International Conference on Control, Instrumentation, Communication and Computational Technologies ",*Kumaracoil, 2015, pp. 796-803.

[4] Z. Yu, "Design of Combustible Gas Detectors in Industrial Premises," *Intelligent Systems Design and Engineering Applications (ISDEA), Fifth International Conference on*, Hunan, 2014, pp. 352-355.

[5] W. Chung, and D. Lee, "Real time muti-channel gas leak monitoring system using CPLD chip," Sensors and Actuators B, Vol. 77, 2001. pp. 186-189.

[6] V. Diduck, "Integrated local or remote control liquid gas leak detection and shut-off system," United States patent No. 6025788, 2000.

[7] L. Fraiwan, K. Lweesy, A. Bani-Salma and N. Mani, "A wireless home safety gas leakage detection system," 1st Middle East Conference on Biomedical Engineering, Sharjah, 2011, pp. 11-14.

[8] Enobong Bassey, Jacqueline Whalley and Philip Sallis ,"An Evaluation of Smoothing Filters for Gas Sensor Signal Cleaning", The Fourth International Conference on Advanced Communications and Computation , 2014, pp.19-23.

[9] Sensors,'MQ-6 Gas Sensors'[online] available from <www.sparksfun.com/datasheets/Sensors/Biometric/MQ-6.pdf>

[10] Pallas-Areny R. and Webster J.G., Sensors and Signal Conditioning, Vol. I, 2nd Ed., John Wiley and Sons, New York, Nov. 2000.

[11] Fraser R.E., Process, Measurement and Control – Introduction to Sensors, Communication, Adjustment and Control, Prentice-Hall Inc., NJ, 2001

[12] Madhu Mohan, N., Geetha, T., Sankaran, P. and Jagadeesh Kumar, V., Linearization of the Output of a Wheatstone Bridge for Single Active Sensor.*Nonlinearity*, *1*(23.79), pp.23-79.

[13] Laddha, M.N.R. and Thakare, A.P."Implementation of serial communication using UART with configurable baud rate". *the proceedings of International Journal on Recent and Innovation Trends in Computing and Communication*, *1*(4), 2013, pp.263-268.

[14] Rahnema, M,"Overview of the GSM system and protocol architecture",*Communications Magazine, IEEE*, *31*(4), 2013, pp.92-100.