SIMULATION OF AN ALGORITHM IN AN ELECTRONIC SYSTEM FOR LPG GAS LEAKAGE DETECTION AND ALERT

Briones Cerquín Angel, Alvarado Rivera Alberto
{u18205516, aalvarado@utp.edu.pe}
Engineering School
Universidad Tecnológica del Perú

Abstract*– This paper allows the simulation of an algorithm applied in electronic devices for leakage detection and alerting different drivers engaged in the transport and distribution of LPG liquefied petroleum gas. Likewise, by using software tools of electronic simulation, we can corroborate the virtual operation of the system with positive results. On the other hand, the electronic components used are for commercial use and can be easily purchased in the market. Due to the current situation, the electronic components will be soon implemented in field. The results in the electronic simulation tool show a system average response time of less than 2 seconds.

I. INTRODUCTION

Currently, there is a great demand for using LPG gas in our country because this energy source boosts the vehicle fleet, helps savings in the domestic usage, provides electricity generation, among other benefits, according to the information provided in [1]. However, a large number of these means of transportation have not been registered in the Hydrocarbons Registry of Osinergmin (Supervising Organism for Investment in Energy and Mining). This Organism is in charge of supervising and inspecting that LPG containers function correctly and comply with the current regulations approved by the State [2]. In addition, the operators of these means of transportation must inform Osinergmin of their routes and timetables in order to keep their circulation safer. Even though these security measures are in force, there is a continuous increase in emergencies due to liquefied gas leaks in recent years, as shown in Table 1, based on data extracted from [3].

CUERPO GENERAL DE BOMBEROS VOLUNTARIOS DEL PERU
COMANDO NACIONAL

ESTADISTICA DE EMERGENCIAS ATENDIDAS A NIVEL NACIONAL
TIPO DE EMERGENCIA - 2021

TIPO DE EMERGENCIA	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC	TOTAL
Incendios	948	692	0	0	0	0	0	0	0	0	0	0	1640
Fuga de gas licuado	720	508	0	0	0	0	0	0	0	0	0	0	1228
Emergencias medicas	1634	1080	0	0	0	0	0	0	0	0	0	0	2714
Rescates	258	186	0	0	0	0	0	0	0	0	0	0	444
Derrame de productos	3	6	0	0	0	0	0	0	0	0	0	0	9
Corto circuito	157	100	0	0	0	0	0	0	0	0	0	0	257
Servicios especiales	162	107	0	0	0	0	0	0	0	0	0	0	269
Accidentes vehiculares	933	739	0	0	0	0	0	0	0	0	0	0	1672
Falsa alarma	211	117	0	0	0	0	0	0	0	0	0	0	328
Otros	134	76	0	0	0	0	0	0	0	0	0	0	210
TOTAL	5160	3611	0	0	0	0	0	0	0	0	0	0	8771

Estadisticas procesada el al %
FUENTE: CUERPO GENERAL DE BOMBEROS VOLUNTARIOS DEL PERÚ

Table 1 – Emergency Statistics 2021
Source: http://www.bomberosperu.gob.pe/po_muestra_esta.asp

Digital Object Identifier (DOI):
http://dx.doi.org/10.18687/LACCEI2021.1.1.540
ISBN: 978-958-52071-8-9 ISSN: 2414-6390

As we provided on the state of the art [4], there are other research papers on monitoring and detecting LPG gas at home or in industrialized plants, but our research focuses directly on leakage detection and control of vehicles transporting this element, avoiding damages and possible human losses. See Image 1.

Image 1. LPG Gas Leak in Tank Truck
Source: https://elcomercio.pe/lima/sucesos/villa-el-salvador-bombas-de-tiempo-todos-los-dias-hay-al-menos-18-fugas-de-gas-en-el-pais-glp-balon-de-gas-bomberos-noticia/

On the other hand, the advancement of simulation tools for an electronic design offers a good approximation of obtaining results that can be implemented in field for a final step. This research uses a Microchip microcontroller as a fundamental piece which has been programmed using a high-level language such as "C" in order to make and understand a logic based on a flow diagram. This will allow the migration to any other microcontroller, if it is desirable, to cover more features and not by using conventional libraries limiting the usage of a specific microcontroller.

For reading sensors and controlling actuators, the analog-to-digital converters (ADC) and coupling are used through a power amplifier, respectively. It has a graphical screen allowing the correct visualization of the LPG gas data expressed in ppm (parts per million). The messages of these gas or emergency values are sent through a Bluetooth module connected to the system. Finally, the entire system can be powered by the battery's own power source.

II. THEORETICAL FRAMEWORK

The basic electronic components used for this research are described in the following paragraphs.

A. MICROCONTROLLER - MICROCHIP

The advantage of using microcontrollers is that we can program an algorithm using a programming language. In our research, we used the high-level language "C" and selected the microcontroller code 18F4550. It is a programmable integrated circuit that has a set of instructions that allows us to program it to fulfill different functions. This microcontroller has an 8-bit data bus, so it is called an 8-bit microcontroller. It has 40 pins and 35 of them are used as inputs and outputs through 5 ports (A, B, C, D and E). In addition, it has some modules such as the 10-bit ADC and the EUSART. The whole architecture allows us to develop the proposed system.

Image 2. PIC 18F4550
Source:http://www.smelpro.com/tienda/pe/circuitos-integrados/92-pic-18f4550-ip-microchip-dip-40-.html

B. LPG GAS SENSOR MQ5

It is a circular metal encapsulation with a mesh that allows the gas to enter into the sensor. It is a digital/analog sensor. It has 4 pins: a VCC pin of positive power supply of 5V, a GND pin of negative power supply, an analog output pin (AOUT), and a digital output pin (DOUT). The MQ5 most accurately detects LPG in the range of 200ppm to 10000ppm.

Image 3. LPG Gas Sensor MQ5
Source: https://uelectronics.com/producto/modulo-detector-de-gas-natural-mq-5/

C. BLUETOOTH MODULE HC-06

The HC-06 is a slave Bluetooth module, which means that it is designed for connection requests. It has 4 terminals: an RXD pin for data reception, a TXD pin for data transmission, a GND pin of negative power supply and a VCC pin of positive power supply that can be from 3.6V to 6V. It uses UART serial communication, and its default parameters are: 9600 8 n 1, which means 9600bps, 8 bits of data length, no parity and 1 stop bit respectively.

Image 4. Bluetooth Module HC-06
Source: https://electropro.pe/index.php?route=product/product&product_id=404

D. LIQUID CRYSTAL DISPLAY

It is a flat screen with a liquid substance trapped between 2 glass plates. In each area or point of this screen there is a liquid crystal. When an electric current pass, the liquid crystal prevents the middle light from passing through this screen, thus displaying alphanumeric characters by means of ASCII code (American Standard Code for Information Interchange). These LCDs are illuminated on the back, so the information can be observed at night. A 16x2 or 2x16 LCD means there are 2 rows for 16 characters each.

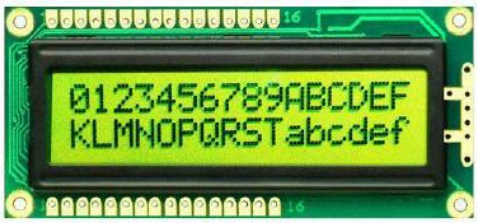

Image 5. Liquid Crystal Display
Source: https://ingenieriaelectronica.org/display-de-cristal-liquido-lcd-definicion-caracteristicas-y-conexion/

III. DEVELOPMENT OF THE SOLUTION

In this section, we describe the five stages related to the development of the project, its characteristics and analysis considered for each stage such as the process of acquisition, control, displaying, and information management.

The indicated stages are described by means of a block diagram. See Image 6.

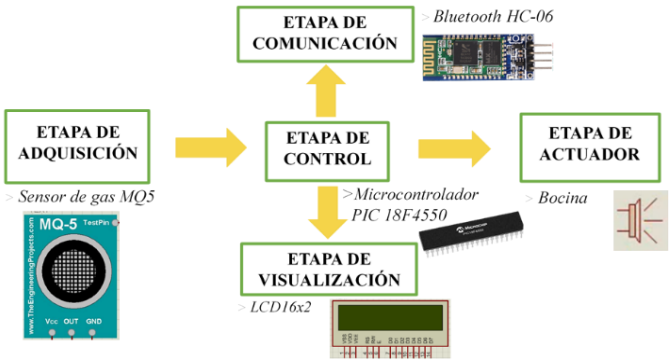

Image 6. Block Diagram
Source: self made:

A. First Stage: Signal Acquisition

In this stage, the signal from the MQ5 gas sensor was obtained. Its behavior was analyzed by means of its technical sheet as shown in Image 7. In this Image, there is a lilac line (LPG) which is a graph of Resistance vs. ppm. It has a higher sensitivity to detect concentrations from 200 to 10000ppm considering that a higher gas concentration, a lower internal resistance and therefore its tension is higher.

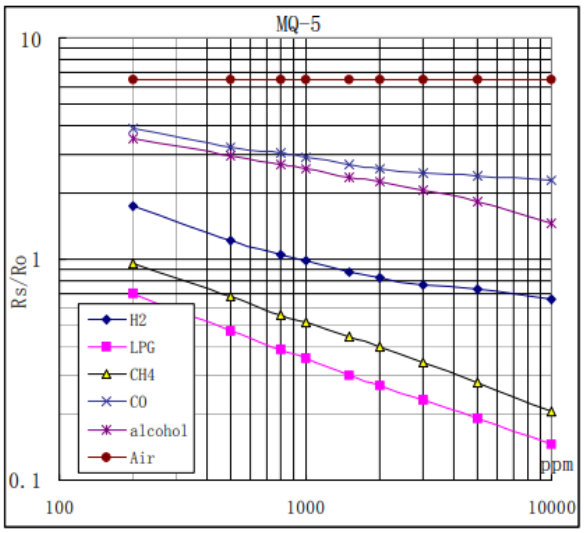

Image 7. Sensor MQ5 Behaviour
Source: https://www.luisllamas.es/arduino-detector-gas-mq/

A part of the programming for the MQ5 sensor is shown in Image 8.

```
#define ACQ_US_DELAY 5  //Para asegurar nuestro tiempo de adquisición de datos (TAD) lo ponemos a 5us

#define VMAX 800      //ESTO SE CAMBIA DE ACUERDO AL PROBLEMA, por ejm acá nuestro ValorMáximo de Concentración de gas GLP
#define VMIN 200.0    //ESTO SE CAMBIA DE ACUERDO AL PROBLEMA, por ejm acá nuestro ValorMínimo de Concentración de gas GLP
#define RESOLUCION 10  //Nuestro conversor (A/D) es de 10 bits

void ConfigADC(void);         //Esto va en el programa principal
uint16_t LecturaADC(uint8_t); //Esto va en el programa principal

#ifdef __cplusplus
}
#endif

#endif /* MIADC_H */
```

Image 8
Source: Self made

In order to take it to the microcontroller, we have set a minimum concentration of 200ppm according to the GLP sensitivity curve of the MQ5 and a maximum concentration of 800ppm as the maximum permissible limit; because the personal exposure/protection control starts from that value, according to the GLP safety data sheet of the company Repsol. See Image 9. [5]

SECCIÓN 8. CONTROLES DE EXPOSICIÓN/PROTECCIÓN INDIVIDUAL

8.1 Parámetros de control

Propano (Nº CAS: 74-98-6):
INSHT (España):VLA/ED: 1000 ppm.
ACGIH (USA): TLV/TWA: 1000 ppm.
GKV_MAK (Austria): TWA: 1000 ppm (1800 m g/m³) / STEL: 2000 ppm (3600 mg/m³).
Lijst Grenswaarden / Valeurs Limites.(Bélgica): TWA: 1000 ppm.
Arbejdstilsynet (Dinamarca): TWA : 1000 ppm (1800 mg/m³) / STEL: 2000 ppm (3600 mg/m³).
TRGS900 AGW (Alemania): TWA: 1000 ppm (1800 mg/m³) / STEL: 4000 ppm (7200 mg/m³).
Rozporządzenie Ministra Pracy i Polityki Społecznej (Polonia): TWA: 1800 mg/m³.
NIOSH (USA): REL-STEL: 1000 ppm (1800 mg/m³).
OSHA (USA): PEL-TWA: 1000 ppm (1800 mg/m³).

Butano (Nº CAS: 106-97-8):
INSHT (España):VLA-ED: 1000 ppm.
ACGIH (USA): TLV/STEL: 1000 ppm.
GKV_MAK (Austria): TWA: 800 ppm (1600 mg/m³) / STEL: 1600 ppm (3800 mg/m³).
Lijst Grenswaarden / Valeurs Limites.(Bélgica): TWA: 800 ppm (1928 mg/m³).

Página 6 de 13 Rev. 3.1 Fecha 13.10.2016

Image 9

B. Second Stage: Displaying Stage

In this case, a 2x16 LCD is configured, which shows a message of the gas concentration through its ppm. If the amount of gas exceeds 800ppm, a new message is activated indicating a LPG GAS leak.

According to the established ranges, the ADC is programmed through the microcontroller registers to transform the analog signal into a digital signal. Details: ADC - AN0, AN1 was configured; VDD and VSS, manual acquisition, Fosc/4 (works at 4MHz) were used.

The LCD message is shown in Image 10, which indicates "GLP GAS LEAK ALERT", displayed when the concentration value is higher than 800ppm detected by the potentiometer.

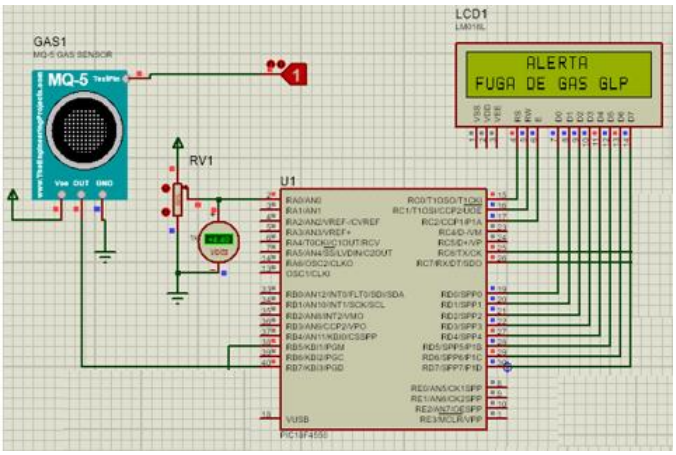

Image 10: Sensor Testing and Handling of LCD
Source: Self made

C. Third Stage: Communication Stage

In this stage, by using the Bluetooth module, it is possible to send an alert message and active the siren when a gas leak is detected.

It works with the microcontroller's EUSART in order to send the communication to the cell phone. In our program, the cell phone is called by a function from the main code. We show the configuration and the created function in the following Image 11.

```
//Configuración EUSART
TXSTAbits.BRGH = 1;      //Alta velocidad (Fact = 16)
BAUDCONbits.BRG16 = 0;   //8 bits (Fact = 16)
SPBRG = 51;              //Para 8MHz y 9600 bps (Fact = 16)

TXSTAbits.SYNC = 0;    //Comunicación Asíncrona
TXSTAbits.TX9 = 0;     //Seleccionamos 8 bits de transmisión
TXSTAbits.TXEN = 1;    //Habilito Tx
RCSTAbits.RX9 = 0;     //Seleccionamos 8 bits de recepción
RCSTAbits.CREN = 1;    //Habilito Rx
RCSTAbits.SPEN = 1;    //Habilito Puerto Serie

void EUSART_Tx(char data)
{
 while( PIR1bits.TXIF != 1 );  //Mientras el TXIF sea diferente de 1, entonces no hacemos nada
 TXREG = data;                 //En cuanto TXIF sea 1, entoces el TXREG está vacio y puedo escribir un nuevo dato
}

void EUSART_Cadena(char *str)
{
 while(*str != '\0') //Mientras el dato sea diferente de nulo entonces
 {
  EUSART_Tx(*str); //Enviamos el primer caracter de la cadena
  str++; //Enviamos los siguientes caracteres uno por uno hasta completar la cadena
 }
}
```

Image 11: EUSART Programming
Source: self made

For the simulation, we use the hyper terminal to send data and its verification in the terminal. See Image 12.

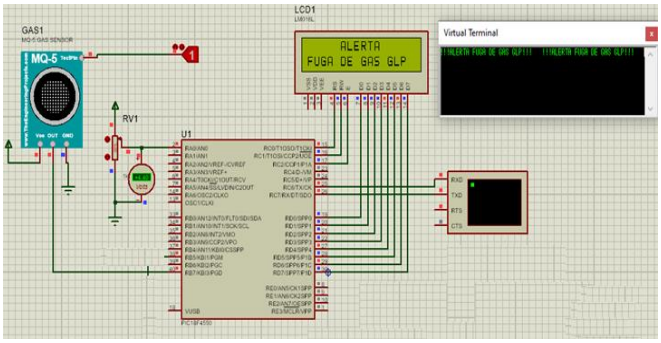

Image 12: Sensor, LCD, and Serial Communication Testing
Source: Self made

D. Fourth Stage: Control Stage

In this stage, we describe our algorithm by using a flowchart. When starting the program, the necessary registers and ports are configured, then we ask if the sensor is activated, if this is the case, we ask for its value and, according to the value, the LCD will show the following actions: GLP < 800ppm (concentration value shown); LPG ≥ 800ppm (Alert - GAS Leak displayed). Image 13

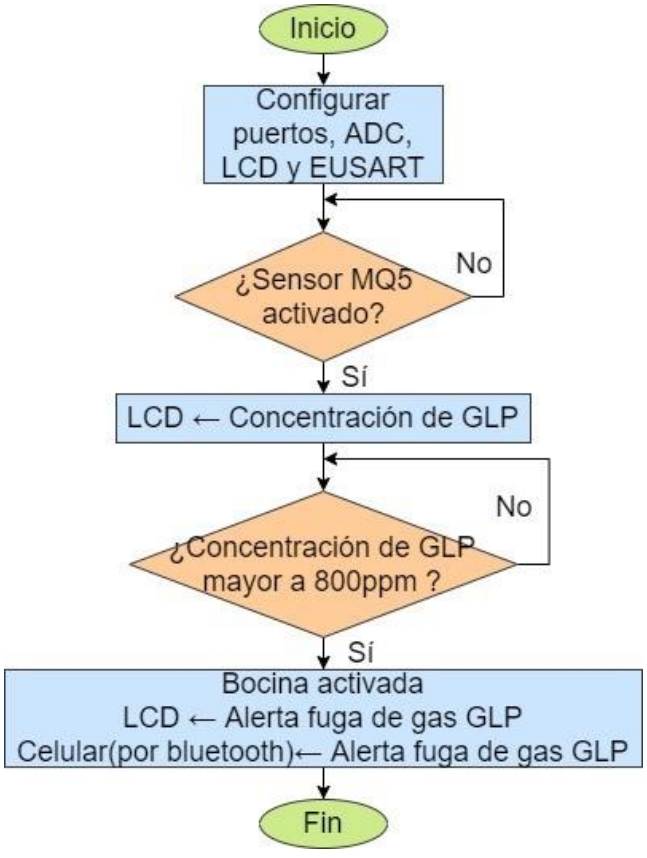

Image 13: Program Flowchart
Source: self made

If there is a leak activation, the siren is activated and the driver proceeds to close the general valve, preventing the LPG gas from continuing to spread.

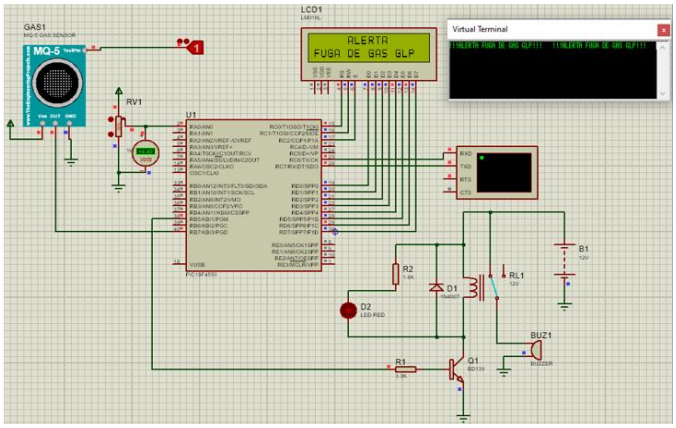

Image 14: Entire System Testing
Source: self made

Next, we show images taken from a video which shows how the implementation will operate in a transport truck of this gas. Likewise, if you would like to watch this proposal in detail, you can find the link in [6].

IV. TESTS AND RESULTS

The simulation tests were conducted considering the transmission and reception times of the message, because our project seeks to obtain a minimum time so that the driver can react immediately. In our case, we obtained an average response time of less than 2 seconds for the message to arrive.

Test done: 08/01/2021

No. of Tests	Starting Time	Activation Time	Activation Average Time
1	00:00	1.9387	1.95524
2	00:00	1.9809	
3	00:00	1.9603	
4	00:00	1.9337	
5	00:00	1.9431	
6	00:00	1.9865	
7	00:00	1.8993	
8	00:00	1.9763	
9	00:00	1.9607	
10	00:00	1.9729	

Table2: test run
Source: self made

Test done: 15/02/2021

No. of Tests	Starting Time	Activation Time	Activation Average Time
1	00:00	1.9187	1.92868
2	00:00	1.9109	
3	00:00	1.9403	
4	00:00	1.8997	
5	00:00	1.9431	
6	00:00	1.9565	
7	00:00	1.8997	
8	00:00	1.9643	
9	00:00	1.9807	
10	00:00	1.8729	

Table3: test run
Source: self made

VI. CONCLUSIONS AND FUTURE RESEARCH

- We concluded that the algorithm works with the electronic simulation tools used in this research according to the tests conducted.
- Response times are less than 2 seconds, which are acceptable considering the fact that the prototype will be implemented in transport vehicles.
- For a future research, this algorithm will be tested through an electronic prototype in order to confirm the correct operation.
- Subsequently, field tests will be first conducted in common vehicles and then in vehicles transporting this type of Gas within the companies of this industry.
- Once the algorithm and the electronic prototype are validated, we will contact companies such as SERVOSA.PE or REPSOL GAS PERU for its deployment at scale.

REFERENCES

[1] https://andina.pe/agencia/noticia-mas-28-millones-personas-se-benefician-con-uso-glp-el-peru-800665.aspx.
[2] www.Osinergmin.gob.pe
[3] www.bomberosperu.gob.pe
[4] Torres Rodríguez, G. (March 2020). Design and implementation of an alert prototype that detects a methane gas leak in a home and activation of protection mechanisms [Undergraduate Thesis]. Universidad de Guayaquil, Ecuador.
[5] https://www.repsol.pe/imagenes/repsolporpe/es/2GLP_tcm76-84132.pdf
[6] https://www.youtube.com/watch?v=OMM5GxT97iw
[7] Guallichico Iza, L. (March 6, 2019). Development of a gas (LPG) leakage monitoring, detection, and control system for domestic use [Undergraduate Thesis]. Universidad Tecnológica de Israel, Quito.