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LPG Gas Leakage and Early Warning Safety System for Households

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Abstract: LPG (Liquefied Petroleum Gas) is a highly flammable gas uses as the main household fuel source which component dominated by propane (C3H8) and butane (C4H10) as a result of conversion from crude oil. Fuels with flammable properties at room temperature need early attention or detection. An early warning and security system built to detect gas leaks in the household, serves as a solution to minimize the losses caused by these leaks. The solution given is a warning sound due to a gas leak using Raspberry Pi as main processor.
Keywords: early warning, embedded system, fire, liquified petroleum gas, raspberry pi

1. Introduction

The security mechanism that has been included in the LPG Gas cylinder, still required to be followed by anticipation of the occurrence of LPG Gas leakage. According to the data released by the National Consumer Protection Agency (BPKN) cited from [1], there were 33 explosion cases caused by gas leakage occurred in June 2010, resulting in 8 deaths and 44 injuries. According to the BPKN document numbered 114/BPKN/8/2010 the main cause of LPG gas cylinder leakage is due to the lifetimeof rubber hoses and regulators that is only one year[2].

Fire is the most commonly hazard caused by LPG leakage beside poisoning. According to the United States Occupational Health and Safety Administration (NISH), the exposure limit of LPG gas in the air is 1000 ppm (part per milion) in an average of ten working hours [3]. Very high concentrations can cause exposed individuals suffer from suffocation. In a short time it can cause fainting, irritation of the nose and throat, headaches, nausea, and vomiting followed by loss of consciousness, shortness of breath and central nervous system depression. Although numbers of security precautions have been included, there are still a number of cases that have an impact on the loss of property and lives as a result of gas cylinder leaks.

2. Overviews

2.1 Fishbone Diagram

The research method used is the Research and Development approach to produce a prototype. Fishbone diagrams are used as one method to identify problems that occur in research. By analyzing existing problems the root of the problems that occur in the study can be found. These problems can be: end users (human or machine), material (hardware), methods or procedures (software), communication or transmission systems and measurement techniques.

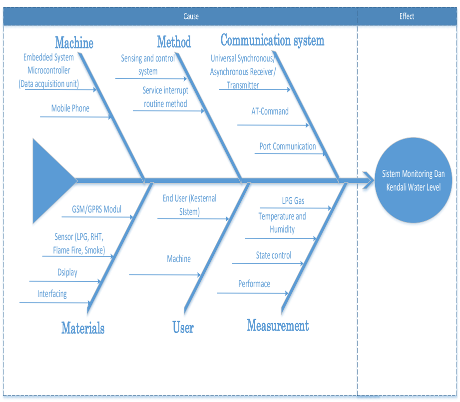

Figure 1 Fishbone Diagram

2.2 System Design

System design classified into two main parts,system fields and end-user applications. The system field is an embedded system developed using the Master Slave communication model. The master in this application was developed using the Raspberry Pi Module functioned as data acquisition and data control. Slave was developed using ATMega 8 microcontroller.

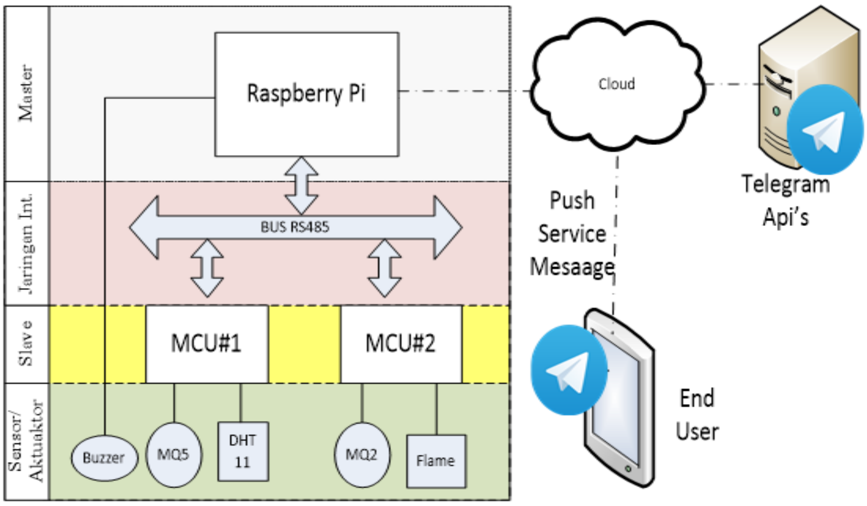

Figure 2 System Diagram Overview

The physical layer in this system consists of sensor devices and embedded systems that are connected via a microcontroller pin interface. The network layer uses BUS network topology with RS485 communication standard. Each node is connected to the BUS network using the RS485 interface. End users connect to the system fields using internet technology through Telegram messaging API 'S for push service. Anomalous conditions in the system provide notifications to end users via the Telegram messaging application.

3. Hardware Architecture Design

The hardware in this system consists of three units: (1) Master microcontroller, (2) Slave, consisting of LPG gas sensor module and humidity and air temperature sensors module, (3) Slave consisting of smoke sensor module and flame sensor module.

3.1 Master (Raspberry Pi Ver. 3B)

The Master is a data processing unit module and decision making on the results of processing data obtained from the slave module. The Master uses the Raspberry Pi version 3B module with a wifi interface for internet access. The master is also equipped with an RS485 chip for the communication interface to the slave module. The use of RS485 communication standards is based on several considerations including: easy connectivity and development of systems, reliable and low cost communication systems. The Master handles acquisition data from sensor measurements and makes decisions on the results of sensing carried out by the slave device. If there is an anomaly over the measurement results obtained due to LPG gas leak detection, the Master device provides a notification via the Telegram messaging API application that is installed on the Master device. Push service technology from the telegram application is used to provide end-user information.

3.2 Slave #1(LPG and DHT Module Sensor)

The Slave #1 device is a sensor module of MQ5 (LPG gas detection) and DHT (Temperature and Relative Humidity Sensors). The microcontroller interface with the MQ5 sensor uses an internal 10-bit ADC on the ATMega8 microcontroller with an internal reference of 5V.

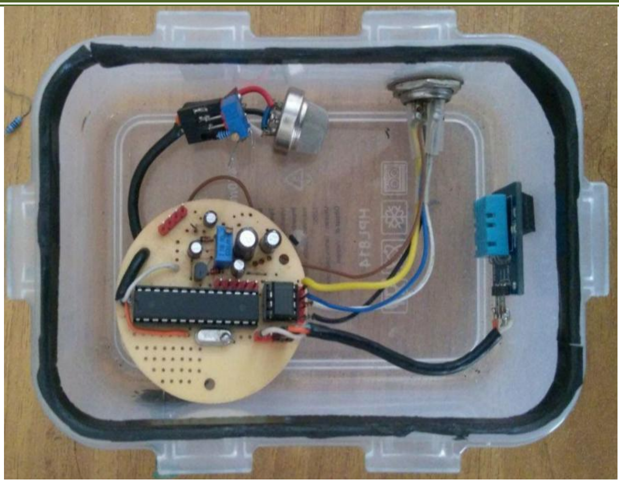

Figure 3 Box is used for calibrating

The calibration of the MQ5 sensor uses the spand reading technique [4] [5] by placing the MQ5 and DHT sensors in an airtight container box with a volume of 0.5L. Calibration is done by injecting LPG Gas liquid with measured concentration into the box. This calibration aims to obtain the threshold value of gas detection that can be used as a reference for decision making on exposure to detected gas concentrations.

Figure 4 Spand readingcalibration

Calibration is done by observing changes in the resistance value on the MQ5 sensor. Zero reading is used as a reference for the value of resistance in open air (without contamination of exposure to LPG gas). Changes in the resistance value according to the characteristics of the MQ5 sensor seen in the graph as in Fig. 5.

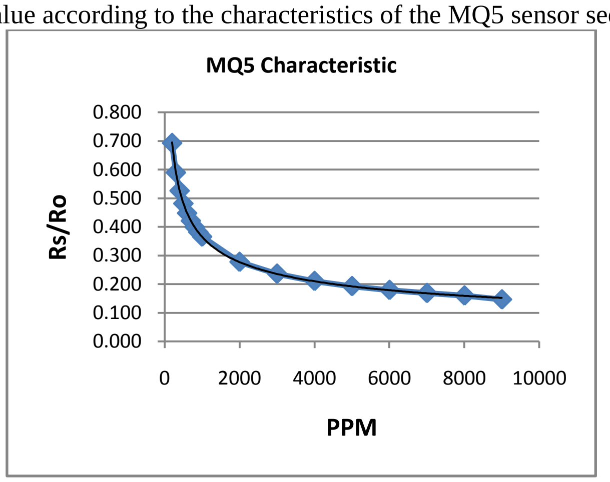

Figure 5 MQ5 Characteristic

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3.3 Slave #2 (Smoke and Flame Module Sensor)

Slave #2 is equipped with MQ2 Sensors sensitive to smoke detection and Flame sensors used for Fire detection.

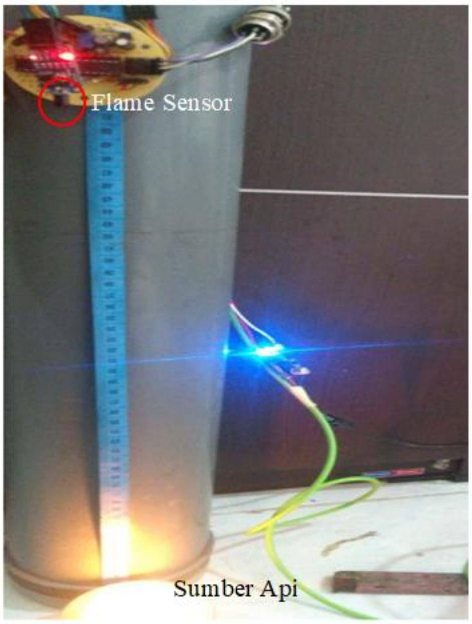

Figure 6 Slave #2 Flame Sensor

Indicators of smoke and fire in a room can be used as variables in determining whether the conditions in the room are in danger or under normal conditions. The MQ2 and Flame sensor modules are connected to the microcontroller using the internal 10-bit ADC Atmega 8 interface.

4. Software Design

4.1 Master Software

The master software is built using the Python programming language on the Raspberry Pi platform. The Python programming language as a language interpreter is able to bridge the design of the model with the hardware. Open source system support and abundant libraries for Python, make this programming language ideal for designing Master module hardware. Interconnection between hardware design and software is shown in the Figure 7.

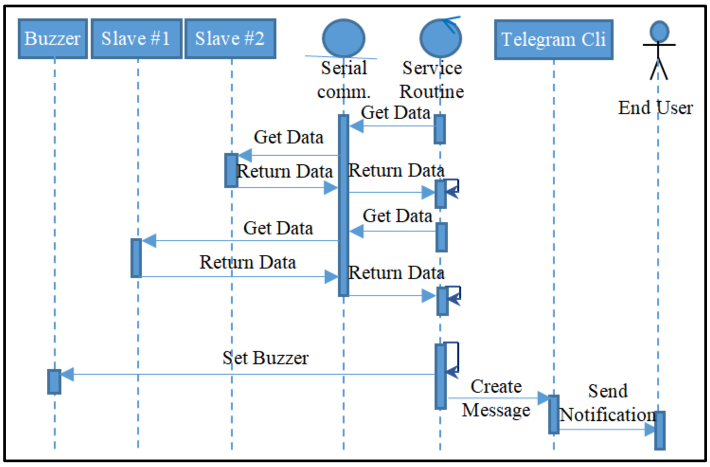

Figure 7 Master software interconnection design

The master periodically sends commands to Slave via serial RS485. An order is sent within 1 second. The slave receives the Master command (get data) and returns the measurement data to the Master. After the Master performs data acquisition, if the measurement results in Slave # 1 state that gas exposure is detected with a level of more than 1000 PPM, the master sets the buzzer and sends a notification to the user via Telegram push service message. The master also sends a message to the user if it detects a significant temperature change and detected a certain amount of fire and smoke exposure.

4.2 Perangkat Lunak Slave

The Slave software was built using the C programming language with the GCC compiler. Slave software is used as a scheduler, where the device takes measurements in 1 second interval. The measurement data is stored in the buffer memory and then transmitted to the Master if requested. Using scheduler can save system resources and make system behavior predictable and coordinated. Figure 8 is the state diagram of Slave # 1 and Slave # 2 software.

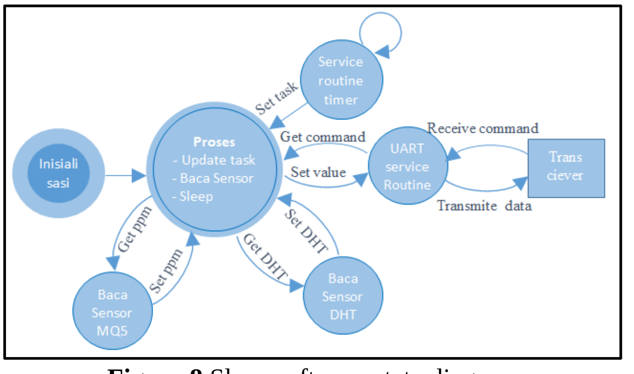

Figure 8 Slave software state diagram

Slave # 1 and Slave # 2 have the same state diagram design. The difference is only in the sensor interface installed on each device. Slave has a unique identification number written in hardcode as the identifier number of each device. The master recognizes the Slave # 1 and Slave # 2 devices based on the identifier number when giving orders and when receiving data, according to the standard protocol frame format that has been set.

5. Implementation

The field system is integrated into the RS485 BUS network using twisted cable (UTP). The end user interface uses a graphical LCD screen display using the Raspberry Pi as the main processor. The end user can monitor the temperature, relative humidity and sensor measurement data on this display.

Figure 9 System Implementation

Push service for notifications using telegram API (telegram cli). Open application support makes it easy to transmit data using push service technology. With this technology, the system can send notifications to end users without making requests through the server.

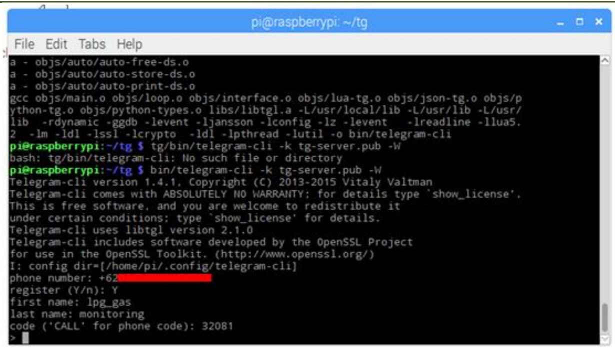

Figure 10 Telegram API Installation

6. Result and Testing

Testing is done by comparing the measurement data (sesor readings) in ppm with the results of the calculation of gas injection into an airtight box. The output of the sensor is stored in a computer log connected to the network system to carry out data dump activities on the network. From the results of the measurements made, the results are as shown in TABLE 1.

Table 1. Measurement Results of Temperature dan LPG Gas Sensor (MQ5)

Tmp	Vrl (Volt)	Rs/Ro	Konsentrasi (ppm)	Pengukuran (ppm)	Error (%)
34	0,591	0,911	100	101	0,01
34	0,75	0,692	200	201	0,01
34	0,856	0,589	300	301	0,01
34	0,935	0,526	400	395	-0,05
34	1,011	0,481	500	505	0,05
34	1,065	0,447	600	595	-0,05
34	1,123	0,421	700	707	0,07
34	1,166	0,399	800	799	-0,01
34	1,213	0,381	900	911	0,11
34	1,238	0,365	1000	973	-0,27
34	1,516	0,277	2000	1973	-0,27
34	1,695	0,236	3000	2973	-0,27
34	1,827	0,211	4000	3995	-0,05
34	1,948	0,193	5000	5187	1,87
34	2,017	0,179	6000	5994	-0,06
34	2,086	0,169	7000	6935	-0,65
34	2,161	0,160	8000	8087	0,87
34	2.241	0,146	9000	9531	5,31
34	2.264	0,147	10000	9987	-0,13

The measurement data shows that there is a difference in results in calculating gas levels. This is due to the lack of accuracy in entering the gas content in the box when testing. The response time for exposure to LPG gas is very good. In the interval of 1 second (4.25 to 5.25) the system detects a very significant change in gas exposure.

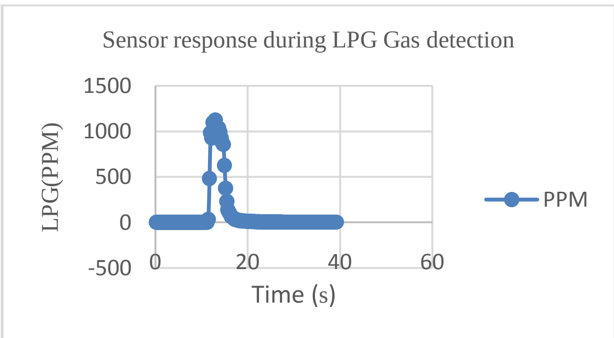

Figure 11 Response of LPG Gas sensor to time

Detection of smoke exposure can be seen in Figure 12.

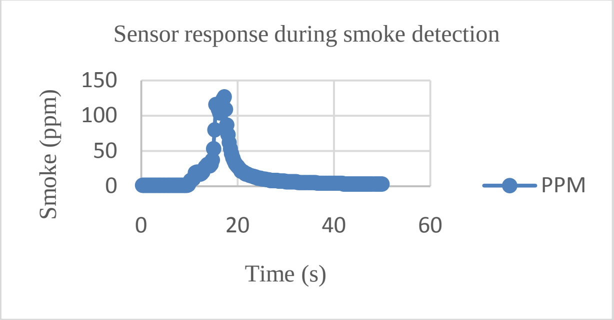

Figure 12: Response of smoke sensor to time

The sensor's response to smoke detection is slightly slower. The presence of smoke begins to be detected and increases within 5 seconds. The peak value change occurs for 2 seconds when the source of smoke is given until the smoke slowly starts blowing into the air (seconds 15.5 to 17.5).

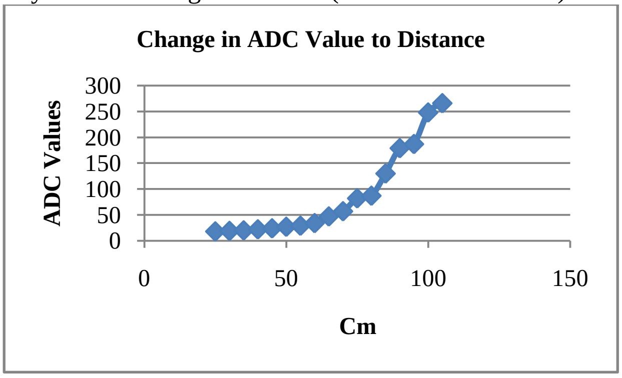

Figure 13 Response of ADC sensor to distance

Changes of the ADC value to the fire detection distance displayed on Figure 13. Changes in the ADC value obtained at ADC 512 resolution with a reference voltage of 5V at a perpendicular angle between the sensor and the hotspot. Overall, the system has worked well, except that the time of sending messages using Telegram services is very dependent on internet network traffic.

7. Conclusion

From the results of the tests carried out, the system is able to work in accordance with the planned initial system design. The error of the detection of exposure to gar LPG exposure was -0.65 to 1.87. The system can respond to gas exposures for up to 1 second and smoke for up to 5 seconds. The system has also been able to send notifications to end users.

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