Arduino-Based Gas and Smoke Detector Realized Using MQ-2 Sensor

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***Abstract*— System for detecting carbon monoxide, particles of smoke and combustible gases is described in this paper. Detector is based on application of Arduino platform with MQ-2 sensor as a source of input signal. The gas sensor functioning principles and detector configuration are explained in details. The described detector could be successfully used for various gas leakage detection, alone, or as a part of more complex system. The experimental results are given for burning paper smoke and three types of combustible gases. They confirm good performance of the system.**

***Index Terms*—Arduino, microcontroller, flammable gas detector.**

I. Introduction

We are the witnesses of rapid growth and wide application of electronic devices and systems in everyday life. The new disciplines and branches of technical sciences have emerged, which are now developing at an even faster pace. Electronic, mechanical and computer science engineering offer implementation of components that enable the development of complex systems that have a wide range of applications in industry, medicine and other fields of human life and work. Protection of human lives and health becomes a primary goal in modern conditions. The Arduino platform has an enormous potential as an educational and research tool, and represents an excellent base for designing important real-life systems. By using the Arduino platform, which consists of a physical part with a microcontroller and of a software, it is possible to design a system that is capable of protecting a human life and goods from fire and combustible gases.

II. System components

Key components for gas/smoke detector system are J1 piezo buzzer, a green and a red LED diode, an MQ-2 smoke detector and Arduino platform. Some of them will be explained in more details next.

A. Arduino

Arduino is an open-source electronics platform, based on easy-to-use hardware and software [1]. Over the years, it has been used for thousands of projects, from everyday circuits to complex scientific instruments. The entire Arduino project has started in 2004. when a Colombian student made a “Wiring” platform for his graduate thesis. In this way a new, low cost, and simple electronic device for fast prototyping was created. Arduino programs are written using a simplified version of C++, which makes it easier to learn. Arduino boards are very versatile and can be used for a variety of different applications. Some of them are: Uno, Due, Mega, Leonardo, Micro, Esplora etc. For the purpose of gas detection system, Arduino Uno was considered quite acceptable. Arduino Uno is the most frequently used variant, since it is very beginner friendly. It consists of 14-digital I/O pins, where 6-pins could potentially be used for the Pulse Width Modulation (PWM) outputs, 6-analog inputs, a reset button, a power jack, a USB connection, In-Circuit Serial Programming (ICSP) header etc., and – ATMega328 [2]. ATMega328 is a high performance AVR microcontroller with 8-bit RISC (*Reduced Instruction Set Computer)* architecture. It has low power consumption and can execute 131 instructions per single clock cycle. It has 32KB ISP (*In-System Programming*) flash memory with read-while-write capabilities, 2KB SRAM, 1KB EEPROM and maximum operating frequency of 20MHz.

B. MQ-2 gas and smoke detector

From 2013. to 2017., there were more than 350 thousand fires per year occurring only in homes, and that number is only a quarter of total number of fires. Smoke detectors are very much needed, since they can help in reducing the number of fires or at least decrease the damage done. Having any smoke detector is better than having none.

Best smoke detectors can detect smoke particles, flames and carbon monoxide. Smart smoke detectors represent a cutting-edge technology for fire safety, since they can communicate through the apps and deliver alerts to a phone or some other device or system. Smoke detectors should always have a backup power source for the case of power loss.

There are two basic types of passive smoke detectors: photoelectric and ionization [3]. Combination of these makes a dual sensor smoke alarm, which is recommended for maximum protection from both fast flaming and slower fires. Photoelectric alarms use light to detect smoke. They sense sudden scattering of light when smoke enters into the detectors chamber, which further triggers the alarm. This method of detection can detect fires that begin with long duration of smoldering aptly. Photoelectric smoke detectors respond from 15 to 50 minutes faster than ionization alarms in early stages of fire. Ionization alarms use radiation to detect smoke [4]. They carry a small amount of radioactive material

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between two electrically charged plates, which ionizes the air and causes current to flow between the plates. The smoke disrupts the flow of ions and reduces the flow of current, which triggers the alarm. Ionization alarms are highly sensitive and respond from 30 to 90 seconds faster than photoelectric alarms to fast flaming fires. This type of detectors is more suited to rapid flaming fire outbursts, unlike the photoelectric detectors, which responds better to smoldering stages. Ionization detectors might perform better where there is risk of fast flaming fire, whereas photoelectric detectors react better to cases of slow smoldering, like electrical or furnishing fire. Dual smoke detectors include both photoelectric and ionization sensors, making them safest smoke and fire detection devices.

MQ-2 is a Metal Oxide Semiconductor (MOS) type of gas sensor, also known as chemiresistor. Chemiresistor is a material which changes its electrical resistance as a response to changes in the nearby environment. Sensors made from metal oxides require high temperatures (200 °C or higher) to operate because, in order for the resistivity to change, an activation energy must be overcome, thus leading us to the conclusion of MQ-2 being more efficient where there is risk of fast flaming fire, as the high temperature will be reached in shorter amount of time[7]. In our case, MQ-2 sensor's resistance changes when smoke or flammable gases are present. It requires 5V DC power supply and draws about 800mW of power. Beside the smoke, it can also detect Liquefied Petroleum Gas (LPG), alcohol, butane, propane, hydrogen, methane and carbon monoxide concentrations from 200 to 10 thousand ppm [5]. The sensitivity curve of MQ-2 sensor for different gases is shown in Fig. 1.

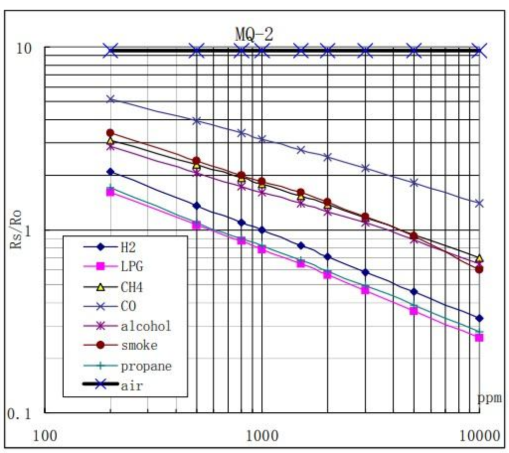

Fig. 1. MQ-2 sensitivity characteristic curve. [8]

Where R_0 is sensor resistance at 1000ppm (*parts per million*) of H_2 in the air, and R_S is sensor resistance at various concentrations of gases.

The sensor is sealed between two layers of stainless steel called anti-explosion network. It is necessary to ensure that the heater inside the sensor does not explode when flammable gases are sensed. The sensor also filters the air particles and allows that only gaseous elements pass inside the chamber. The anti-explosion network is attached to the enclosure with a copper plated clamping ring.

Fig. 2. MQ-2 external structure.

Figures 2 and 3 show the external and internal structure of the MQ-2 sensor.

Internal star-shaped structure is formed from sensing element and six connecting legs. Two of six leads, (H in Fig. 3.) are dedicated for heating the sensing element and connected through the nickel-chromium coil (conductive alloy). The remaining four leads (As and Bs in Fig. 3) generate the output signal and are connected using platinum wires which are linked to the sensing element and deliver small changes in the current that passes through the sensing element.

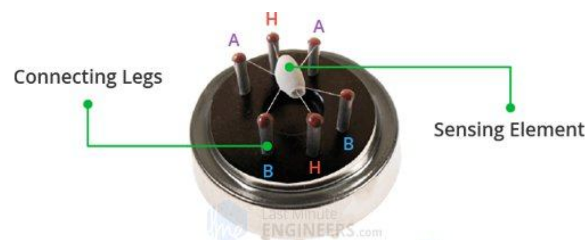

Fig. 2. MQ-2 internal structure. [9]

Sensing element is made of aluminum oxide and a tin dioxide coating. Tin dioxide coating is the most important part of the component since it is sensitive to combustible gases. Aluminum oxide increases the heating efficiency and ensures that the sensor reaches the working temperature.

If the air is clean, donor electrons from tin dioxide are attracted toward oxygen adsorbed on the surface of the sensing material, which prevents electric current flow as shown in Fig. 3. In the presence of smoke or combustible gases, oxygen reacts with gases which causes decrease of the surface oxygen density. Electrons from Fig. 5. are released back into the tin dioxide, allowing the current to flow through the sensor.

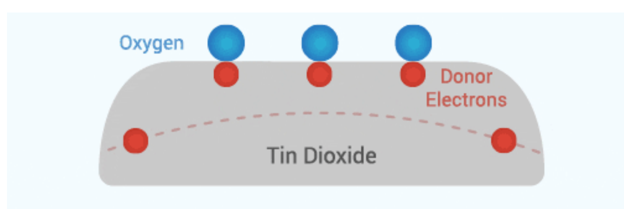

Fig. 3. Absorbed oxygen in clean air prevents the current flow.[9]

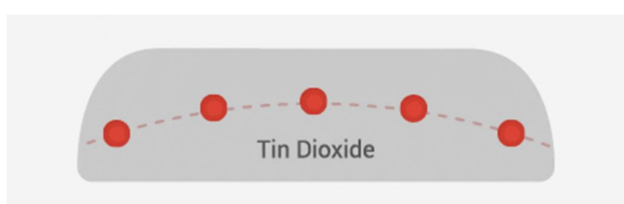

Fig. 4. Electrons are released into the tin oxide in the presence of

gas/smoke.[9]

The generated output voltage of the sensor is proportional to the concentration of the present smoke or gas. Higher gas concentration causes higher output voltage. The analog signal from MQ-2 is digitized as in the case of Arduino board based gas detection system implementation.

III. System Realization

For simulations and realization of this project, software environment “Fritzing” was used [6]. Fritzing is an open-source hardware initiative mainly used for documenting and sharing prototypes, layouts and manufacturing of Printed Circuit Boards (PCBs).

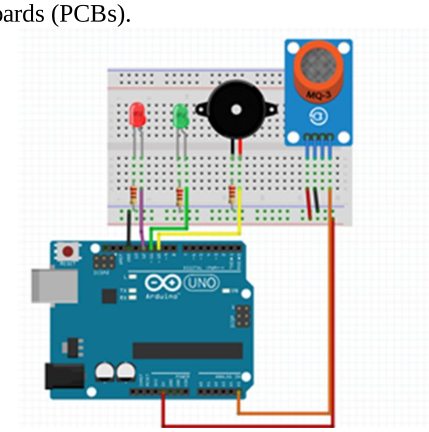

Fig. 5. Breadboard realization of the system using Fritzing.

Breadboard realization of the system using Fritzing is shown in Fig. 5.

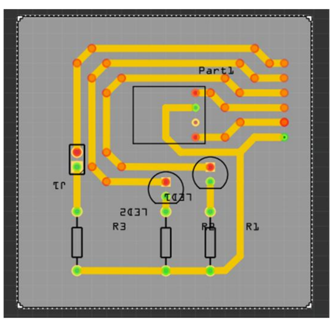

Fig. 6. PCB of our project.

PCB of the smoke/gas detection system is shown in Fig. 6.

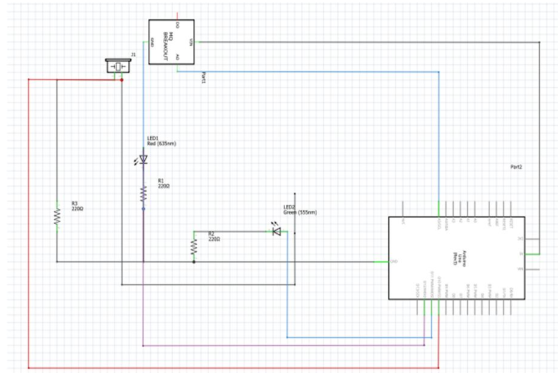

Fig. 7. Schematic of the system.

Schematic diagram of the system is shown in Fig. 7.

IV. The Experimental Results

The verification of the described detector system is performed in modest improvised laboratory environment. The greatest attention is paid to the fact that all measurements are performed in similar conditions as would be expected in real-live scenarios. In order not to endanger household safety, the measurements were performed inside a pan with a lid, as shown in Fig. 8. In this way a sufficient concentration of gases and good sensor response to small amount of gas is achieved.

Fig. 8. Experimental conditions.

Experiments show that smoke sensitivity of MQ-2 is considerably lower than its sensitivity to combustion substances (butane, alcohol and LPG in our case). This can be noticed from Fig. 10. After conducting multiple measurements, we could calculate the detector’s sensitivity value (slope of the given characteristics) for different gases using the following equation:

$$u_{A5}(nT) = 5\frac{A5}{1024}\,[V],\quad T = 102\,ms \tag{1}$$

where u_{A5} is voltage on analog pin A_5 with maximal possible value of 5V. A_5 is a digital representative of measured voltage on the sensor with maximal value of 1024.

experiment was conducted, obtained sensitivities cannot be considered as very accurate. The source of LPG was a 20l gas bottle. In short time it can deliver larger amounts of gas than a lighter (used as a source for butane). It is also noticed that the sensitivity to alcohol vapors is slightly lower.

Measured results are in compliance with data from Fig. 1, while maximal sensitivity is obtained for the LPG. Home conditions were not very satisfactory because the main priority was not to burn the sensor (small distance from the fire), while maintaining to "feed" the fire by removing the lid regularly. Real time information from Serial Monitor detected the smoke concentration drop with lid removal (to obtain more paper fuel) and this caused slow increase of sensor output voltage.

At the end we can conclude that with the right calibration, the MQ-2 can be used for detecting (and alarming) larger quantities of combustible gases in houses or storages.

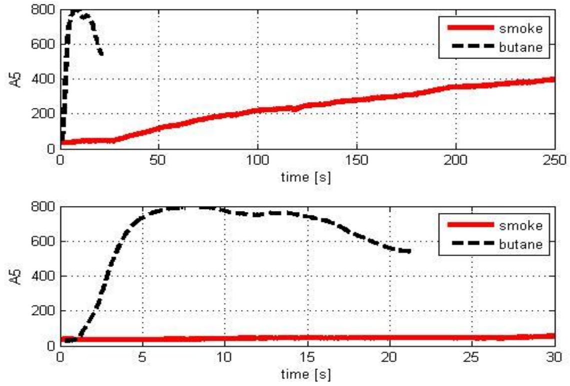

Fig. 9. Measured voltage for smoke and butane.

The relevant measure of sensor sensitivity could be the sensor's output voltage change rate $\frac{du_{A5}}{dt}$.

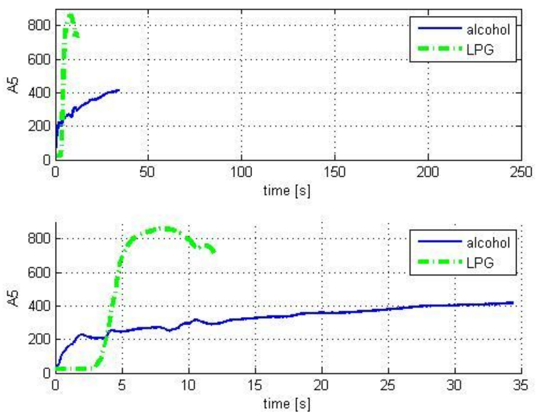

Fig. 10. Measured voltage results for alcohol and LPG.

That value is estimated from collected data, shown in Figs. 9 and 10, taking into account only part of the curve where the slope was constant and maximal.

- Butane: 0.9896 $V*s^{-1}$
- Alcohol: 0.5127 $V*s^{-1}$
- LPG: 1.8815 $V*s^{-1}$
- Smoke: 0.0145 $V*s^{-1}$

Measured voltage values were shown in *Serial Monitor* view in Fritzing, and it allowed us to track results in real time via serial data transfer (In this case it was set to 9600 bauds). Gathered data was imported in MATLAB after which it was used to generate the above characteristics. Those graphs show cumulative data. The latter graphs are zoomed and show curve parts where MQ-2 shows significant change when detecting larger amounts of gas.

One can conclude that MQ-2 is very sensitive to gases mentioned above. Considering the conditions in which

V. Conclusion

In this paper one possible solution for realization of detector system for recognizing presence of smoke or combustible gases is presented. System is tested in home conditions with exposing MQ-2 sensor to different types of gases. Output sensor voltage is monitored for smoke generated by burning papers and cigarets and for available combustible gases as butane from lighter, stove LPG and alcohol vapors. Experiments prove high sensitivity of MQ-2 sensor making it a good choice in detector system basic sensor selection. By combining with other types of sensors, it is possible to create more complex detectors.

Acknowledgment

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