Design and Implementation of a Low Cost System to Determine the Composition of Biogas

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***Abstract*—The main objective of this work is the design and development of a device similar to a continuous gas sensor, which can analyze the composition of combustible gases, depending on the types of sensors installed in the capsule designed for this purpose. Some manufacturers of continuous gas analyzers develop equipment with high price. The purpose of this work is the design and implementation of a low cost system, affordable to any type of company, based on the platform Open Hardware Arduino, for measuring and analyzing biogas. This system can be used for many applications and because biogas is a renewable gas fuel, it will be increasingly important in countries committed to the reduction of greenhouse gases. All circuits will be designed and later simulated with the Multisim 12.0 software. The printed circuit boards will be created with the help of the Ultiboard 12.0 software and, finally, the necessary files will be created for the printing of these circuits in the plates with the software LPKF CircuitPro 1.5.**

Keywords-continuous analyzer; combustible gases; biogas.

I. INTRODUCTION

Continuous gas analyzers are equipment that analyzes the composition of gases continuously. That is, as the gas is flowing through the analyzer, the reading of the gas composition can be instantly obtained.

Focusing on combustible gases, these are used for the production of thermal energy from a combustion process. Some gases of this type are natural hydrocarbons and those manufactured solely for use as fuel. Among all possible cases, it has been decided to develop a prototype to determine the composition of biogas. The composition of this combustible gas varies according to the origin of the same [1]. Biogas can be generated in natural media or in a sealed, oxygen-free tank called anaerobic digester, from the reactions of biodegradation that are produced of the organic matter, by the action of microorganisms in the absence of oxygen [2].

This combustible gas consists of a mixture composed of 50-70% of methane (CH_4) and 30-50% of carbon dioxide (CO_2). It also contains minimal amounts of other gases, such as nitrogen (N_2), hydrogen sulphide (H_2S), and some traces of water vapor. The calorific value of the biogas will vary its value depending on the proportion of methane in the mixture [3].

The measurement system designed in this work is based on four sensors that have been chosen according to the composition of this renewable fuel gas. However, it can be extrapolated to any other type of gas simply modifying the set of selected sensors.

The rest of this paper is organized as follows. Section II describes the sensors used. Section III describes the developed prototype. The conclusions and acknowledgement close the article.

II. SENSORS FOR COMBUSTIBLE GASES

Regarding the monitoring of combustible gases, sensors are required that can detect high concentrations of gases, compared to those required for toxic gases that must be more sensitive to lower levels of concentrations.

For both cases, there are five types of sensors, each based on a different foundation for the detection of different gases, namely electrolytic sensors, catalytic sensors, solid state sensors, infrared sensors and photoionization detectors.

Among all types of gas sensors, semiconductor type sensors have been chosen. These sensors have a thin film of metal oxide, on which a piece of silicone is deposited. The absorption of gas at the surface with this oxide results in a change in the electrical resistance, which is related to the measured gas concentration of the sample.

The following sensors have been selected for the implementation of the biogas measurement and analysis system: ammonia (TGS2444), hydrogen (TGS821), methane (TGS3870) and carbon monoxide (TGS5042) sensors [4]. Fig. 1 depicted the sensors selected along with their interface circuitry. The sensors have been bought as ready product but the interface circuitry have been fully designed and built.

III. DEVELOPMENT OF THE PROTOTYPE

This section deals with the design and theoretical development of all the circuits involved in the biogas measurement and analysis system. All circuits will be defined theoretically and, later, simulated by the software Multisim 12.0. Printed circuit boards will be created with the help of Ultiboard 12.0 software. Finally, the necessary files will be created for the machine responsible for printing these circuits on the plates with the LPKF CircuitPro 1.5 software [5].

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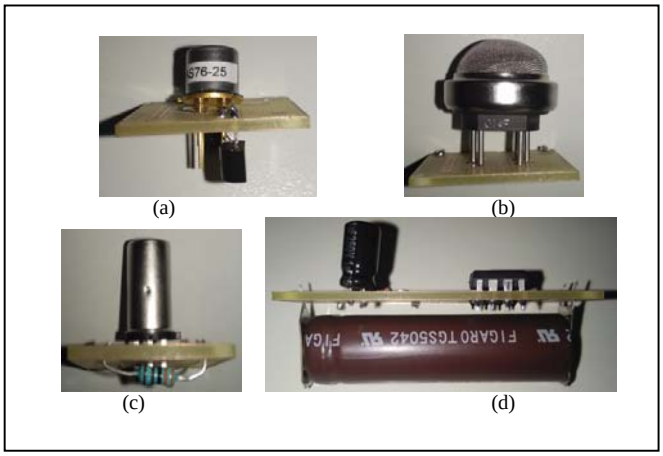

Figure 1. Sensor used: (a) ammonia, (b) hydrogen, (c) methane and (d) carbon monoxide

In this research, an Arduino board, model MEGA2560 has been used as Data Acquisition system (DAQ) for the set of sensors. It is based on a microcontroller ATmega2560. Analogue input channels are used to measure the voltage of the output circuits of the sensors. The cost of Arduino MEGA is noticeably lower than the cost of a traditional DAQ. The carbon monoxide sensor is the cheapest, 28€, whereas the ammonia sensor costs 90€. The system total cost is about 300€. The cost of the Arduino board is 40 €. A DAQ with analog inputs costs over 450€ in the market, so the low cost character of the proposal is clearly stated.

A methacrylate capsule has been designed with Autodesk AutoCad 2013 and Autodesk Inventor 2014 software, which will circulate the biogas to analyze and house the sensors used (Fig. 2a). Fig. 2b shows a snapshot of the hydrogen sensor as sample of the developed prototype.

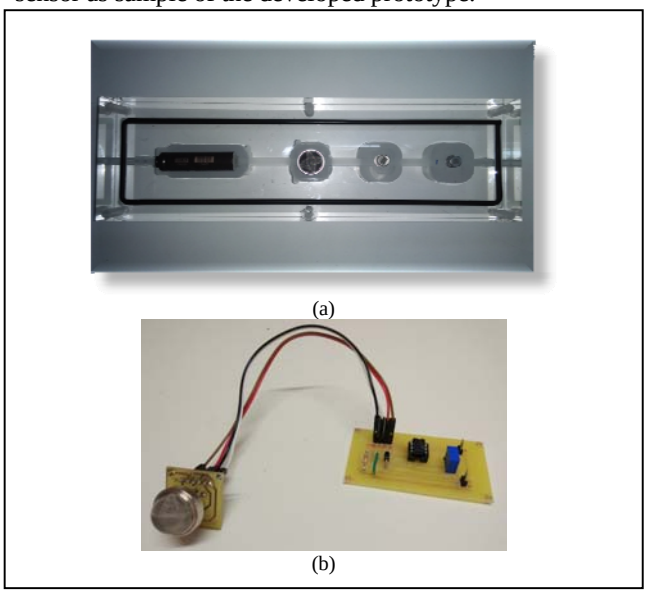

Figure 2. Appearance of: (a) Methacrylate capsule containing the sensors and (b) hydrogen sensor.

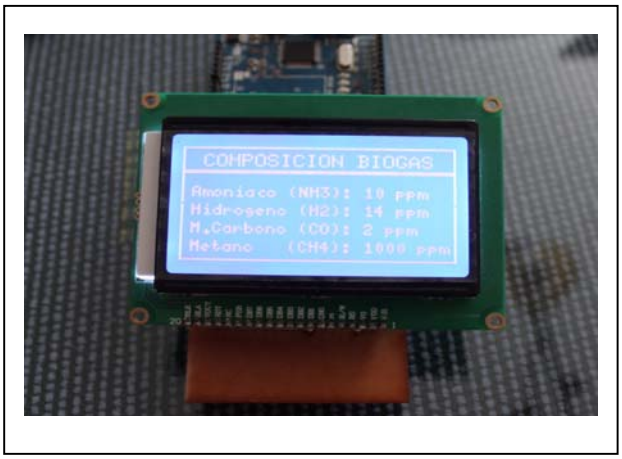

Figure 3. Preliminary experimental results.

Early results are shown in Fig. 3 where a snapshot of the system working under laboratory conditions can be observed.

IV. CONCLUSIONS

In this work, the design and development of a cost-effective continuous gas analyzer has been reported. Each of the four sensors chosen for the detection of the biogas composition has been studied and analyzed. Besides, all the circuits necessary for this purpose have being realized. All the circuits that compose the system of measurement and analysis of biogas have been simulated with the software Multisim 12.0, obtaining at all times the corresponding values exposed in the sheets of characteristics of each of them. All the printed circuit boards of the circuits necessary for this project have been implemented with the software Ultiboard 12.0. Currently, the developed meter is in the test phase in order to validate the proposed system.

ACKNOWLEDGMENT

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