

A Hardware for Conditioning and Improving Signal from Carbon Oxide Sensing System

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Abstract—A precised and accurate measurement of environmental pollutants is not always an easy task if we are in presence of variable quantities depending on the process under test. The signal conditioning of sensors dedicated to environmental monitoring is an aspect that strongly impacts on the quality of post processing. The paper presents a design of conditioning circuit for a pyrosensor of carbon oxide emitted by industrial and human activities. The conditioning circuit can be also used for home pollution monitoring in the context of heating and it can be useful for automotive applications too. The conditioning circuit automatically allows the detection of necessary level of pollution in order to produce an alarm to be deployed and/or relay to be acted.

Index Terms—Air pollution, carbon oxide, sensors, conditioning circuits

I. INTRODUCTION

The effects of carbon oxide are well known especially their impacts on environment [1] and human health. For many cases and situations involving the measurement of pollutants [2] as per carbon oxide, it is necessary to have a good chain of measurements in order to correctly process the signal received from the sensor. For this reason conditioning circuits are necessary. When we deal with carbon oxide, we should remember two specific components that is, we have carbon monoxide (CO) and carbon dioxide (CO₂). Both pollutants are important for civil and industrial activities. However it is suitable to point out sources of carbon oxide. Carbon monoxide is generally produced, every time substances containing carbon, are burned with less air but however even when the amount is sufficient, the reaction does not take place until the completion, and oxygen and carbon monoxide are present in the gas. Combustion is a process of quick oxidation of combustible material with a combustive agent [3]. More than 70% of CO present in the atmosphere is the result of cars supplied with gasoline and diesel fuel. As it is previously expressed, CO is given off due to incomplete combustion of methane (CH₄), gasoline, diesel fuel, kerosene, combustible oil etc., and it is emitted by motors [4], thermal plants, oven/furnaces, boilers. High concentration of CO can be also reached in underground rooms or isolated external milieus where cars and vehicles are in parking position but with motors that are switched on. These conditions of CO production are also encountered where biological processes are carried out as in wineries or cellars, open reservoirs for sewage plants. There are different techniques for detecting CO and CO₂ that

have been improved. The most important technology used for fabricating sensors for gas detection is semiconductor. Within this technology we find chemical sensors for revealing gas. In general a chain of chemical detection system contains the following subunits: one or more sensors and signal processing systems. A chemical sensor [5] is a device that transforms a chemical information, like concentration or composition of a sample to be analyzed, into usable signal (electrical or optical). The chemical information is from a chemical reaction of the sample to be analyzed or from a physical property.

A chemical sensor is not an autonomous system but it represents one the essential components of an analyzer. Other subunits like analyzed sample transportation, sample conditioning, processing signal outcoming from sensor, etc.. can complete the chemical sensor in function of the application.

The detecting part of such a system can be constituted by two main parts. The first part regards receiving or primary transduction: that means the conversion of chemical information into physical or electrical one [6]. This kind of conversion is exhibited by sensors based on the measurement of absorbance, refraction index, mass modification, etc... in the second case, we deal with modification of electrical characteristics of the sensor (charge, impedance, permittivity) after a chemical reaction. We call transduction, the principle used to perform one of the aforementioned transformations. Principles of transduction of a chemical sensor are numerous: optical, electrochemical, electrical, based on mass, thermal-electrical, etc.. [7].

The second part is conditioning, that is the circuit including the sensing cell to obtain an useful and exploitable signal, image of physical or electrical information. This is called secondary transduction. According to system viewpoint, and in basic way, the sensor can be modeled as the cascade of the above transductions. Performances of a gas sensor depend upon six principal characteristics: sensitivity, selectivity, stability, reversibility, response time and reproducibility. We just illustrate sensitivity since it is a main factor for signal quality. It expresses the variation of sensor response in function of measurand (gas concentration). A gas sensor is called sensitive [8] if a small variation of concentration produces an important variation of output signal. The general definition is given by the following

$$S = \frac{\Delta R}{\Delta C} \quad (1)$$

where S is the sensitivity, R is the response of the sensor and C is the gas concentration. Gas sensors based on metallic oxide, as it is in this paper, are passive sensors which variations can be only measured by integrating the sensor in a conditioning circuit (potentiometric installation, wheatstone bridge,..). Variation of ambient conditions or gas concentration produces a change of conductivity of sensitive material that contains semiconductors based on metallic oxides. Stain dioxide (SnO₂) is one the most important semiconductor [9] followed by a mass production thanks to component industries. In gas sensors based on semiconductors, chemical information is translated by means of electronic structure of the material and its surface into measurable electrical characteristics, namely change in conductivity. In fact, in order to be measurable, interactions based on chemisorptions [10], are mainly oxidation-reduction reactions that allow electronic exchanges between gas and sensitive material.

II. THE USED SENSOR

In general, a semiconductor gas sensor is constituted by a sensitive material (SnO₂), tin oxide, and suitably doped by a heater. The principle of operation [11] is based on the increase in electrical conductivity when the porous surface of the material is in contact with a mixture of air and gas. The dopant material is, copper oxide, carbon, platinum for the methane, and the heating temperature of the sensitive material to make the transducer selective relief of a specific gas.

The semiconductor sensor (Fig.1) is formed by a metallic cell, from a ceramic substrate, on which the doped semiconductor anchored to two electrodes is deposited, and there is a filament capable of heating the sensing element up to 500 ° C.

To convert the resistance change in the voltage variation (Fig.2), we can use a resistive voltage divider, in which the sensor resistance RS is placed in series to the resistance RL of utilization or a Wheatstone bridge in which the resistance RS of the transducer is located arranged on a branch of the bridge.

The transducer TGS8812 [12] is suitable for detection of carbon monoxide (CO) (toxic gas), isobutane gas (fuel) and

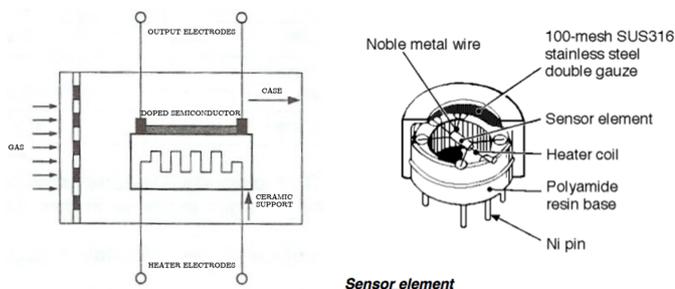


Fig. 1. Sensor CO TGS812 Figaro series

CO concentration in the air [%]	CO concentration in the air [ppm]	Toxic symptoms demonstrators and times of inhalation
0,01	100	Slight headache within 2-3 hours.
0,04	400	Pain in the forehead within 1-2 hours. Become stronger after 2,5-3,5 hours.
0,08	800	Vertigo (dizziness of lightheadedness), nausea and convulsions within 20 minutes. The man loses consciousness within 2 hours
0,16	1600	Headache, dizziness, lightheadedness and nausea within 20 minutes. Death occurs after 2 hours.
0,32	3200	Headache, dizziness, lightheadedness and nausea within 5-10 minutes. Death occurs within 30 minutes.
0,64	6400	Headache, dizziness, lightheadedness and nausea within 1-2 minutes. Death occurs within 10-15 minutes.
1,28	12800	Death occurs within 1-3 minutes.

TABLE I
INFLUENCE ON HUMAN HEALTH

the organic vapors (ethanol). Table I depicts the effects of carbon oxide on human being.

Fig.3 shows the value normalized resistance RS of the transducer as a function of concentration of certain gases expressed in ppm. R0 is the resistance of the sensor for a gas concentration of 1000 ppm for methane. (5 to 15kΩ). RS is the resistance of the sensor the different concentrations of gas.

III. DESIGN AND SIMULATED CIRCUIT

The main idea of the design is to use the sensor as on/off component for determining the overcoming of concentration values established by technical and legal rules. But this overcoming concentration value must be determined in an accurate way. That is why a conditioning system must be designed accordingly. The simplicity of the circuit is related to the use of comparator without combining it with a 555 timer [13]. One may know that 555 timer (Fig.4) has a stable time delays or free running oscillation. The time-delay mode is RC –controlled by two external components. Timing from microseconds to hours is possible. The oscillator mode requires three or more external components, depending on the desired output waveform. Frequencies from less than 1 Hz to 500 kHz with duty cycles from 1 to 99 percent can be attained.

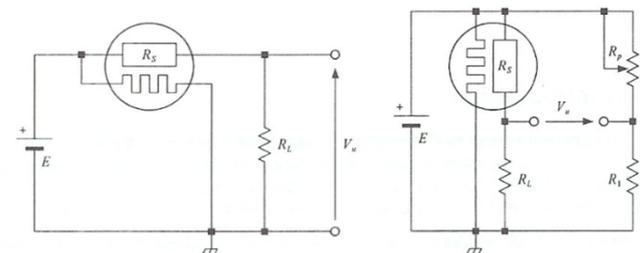


Fig. 2. (a) Resistance voltage divider (b) Wheatstone bridge

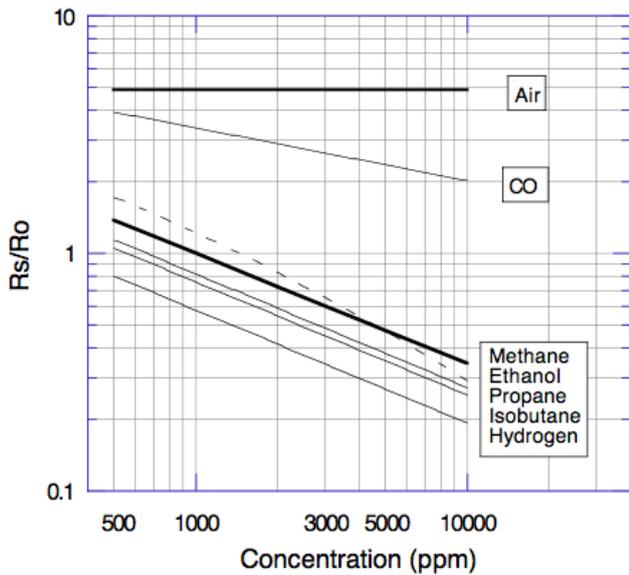


Fig. 3. Resistance vs concentration

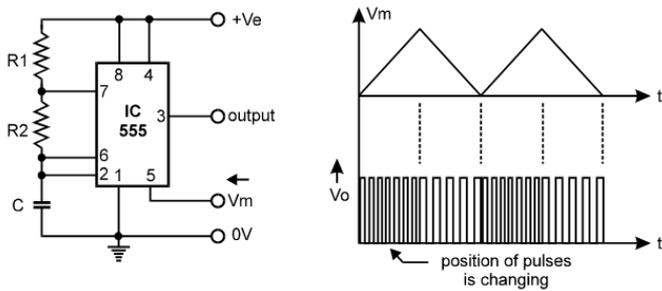


Fig. 4. Functional block diagram of the NE555 and amplitude vs pulse

The above description allows to understand how the idea of the paper is very simple since it uses a comparator for the conditioning circuit that has been designed using Proteus environment [14]. The circuit uses a pyrosensor series Figaro TGS812 especially designed and fabricated for the detection of carbon monoxide. This type of pyrosensor varies its resistance depending on the concentration of gas present in the environment. The active circuit is controlled by the number assigned to the operational amplifier mounted as UA741 comparator. The threshold is adjusted by RV1 trimmer, RV2 trimmer instead of the level any tolerances between the sensor and the sensor.

In order to allow the circuit to operate properly, It is necessary that the pyrosensor reaches the operating temperature by the heating element located inside. For this reason it is necessary to make an initial calibration after about 30 minutes, and then a second calibration after 24 hours of operation. The circuit is powered by a 12 V and is designed for driving a solenoid or an external reed relay, as one can see the reading voltage at the terminals of the voltmeter included in the circuit.

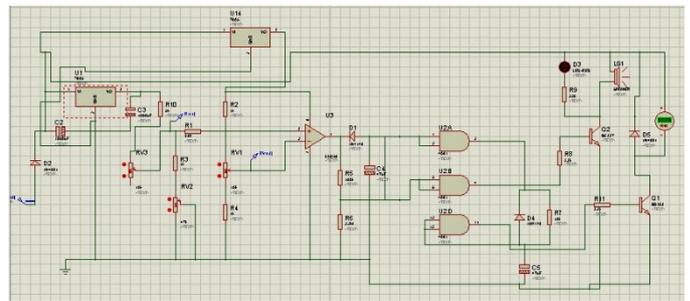


Fig. 5. Schematic circuit in Proteus

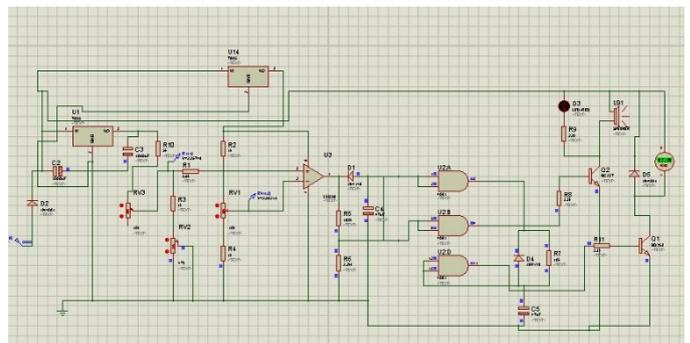


Fig. 6. System with CO concentration under threshold

IV. RESULTS

As we say in previous sections, the conditioning circuit is designed to allow an on/off operating mode. Once the circuit has been designed according to circuit of Fig.5, it has been simulated in order to see its response to virtual input related to a gas. It is a small circuit capable of driving the sensor output using analog and digital components.

Once calibrated the system we simulated two different situations; concentrations below a threshold, which is set to approximately % of full scale of 1000 ppm, and concentrations over threshold with two different behaviors of the circuit. In the first case (Fig.6) we see that the output voltage from the sensor is lower than the previously set threshold voltage and the LED light [15]–[17] controlled digitally remains off and the voltage read on the voltmeter dc is zero. In the second case (Fig.7), the sensor voltage is greater than the threshold voltage and activates both the LED light that has a voltage of 11.2 V across the dc voltmeter instead of 12 V due to the voltage drop of the interposed diode.

This approach, related to threshold, is important for confined environments like houses, rooms and offices. The threshold approach could use an alarm of level of pollution degradation before the worse conditions. In fact, many monitoring systems provide different steps of alarming, that is, level of attention, threshold level and dangerous level. The loud alarm can be combined with a light one, for example for houses where methane gas is used for heating and cooking; in this way, a double alarm is necessary because elderly persons are always hosted. However, the same approach can be adopted for traffic

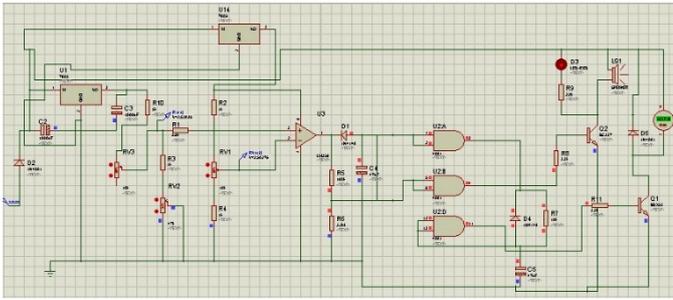


Fig. 7. System with CO concentration over threshold

control, including this kind of system in a smart city project [18].

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