Aspects of TGS 813 Gas Sensor´s Use

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Abstract: Aspects of air polution and health protection are now prioritary problems for researchers and establishing the dangerous gas concetration in the air allows the initiation of actions destined to avoid both types of problems. Due to the mentioned reasons, the sensors, equipments and methods of establishing the grade of dangerous substances mixture in the environment are of great interest in the scientific world. In this paper are presented aspects regarding the use of TGS183 sensor for the detection of the concetration level of denagerous gases in the air, namely approximation of the characteristics, dependent on the temperature and relative humidity in the measure point. The obtained results facilitate the use of these sensors in embedded systems dedicated to the measure of gas concentration in the air, realised with the help of microcontrollers.

Keywords: sensor, gases, characteristics, nonliniarity, measure

1 Introduction

In many places is necessary to detect burned gases (carbon monoxide) or gases (methane, butan, hydrogen), which together with air form a mixture, that can explode. In enterprises where such gases are used, the monitorisation of their concentration is very important in order to avoid catastrophes.

Not only in production departments is a gases´ monitorisation important, but also in all-day life; we reach situations in which it would be good to know, for example, how much the carbon monoxide concentration in a room is, because not rarely, it´s exceeding has had tragical consequences. The concentration´s increase over 880 ppm, namely 0.08% is dangerous for humans. Taking into consideration the danger presented, there were concerns, and equipments for gas detection already exist. [1]

In the technical world there are sensor producers [2], who detect either only one type of gas or more types. In this paper we will refer to the posibilities of using a sesnor that can detect methane, butane, hydrogen and carbon monoxide [3], connected to an equipment based on a microcontroller.

2 Sensor’s Characteristics

According to catalogue data [3], the sensor used (TGS 813) to detect the gas concentration has the nonlinear sensitivity feature (se Fig. 1) (representation is in logarithmic scale) and is dependent on the temperature and humidity of the environment (see Fig. 2) where it is placed. It is noted: R_0 = the sensor´s resistance in 1000 ppm methane, R= the sensor´s resistance to different concetrations of various gases.

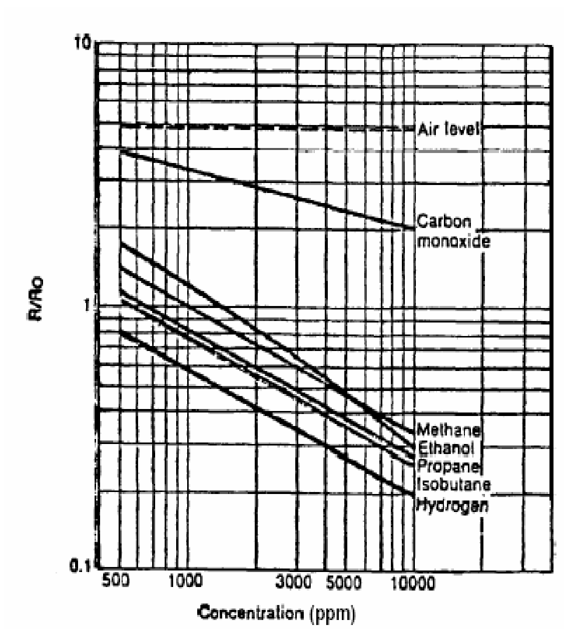

Figure 1
TGS#813 sensor’s sensitivitv feature

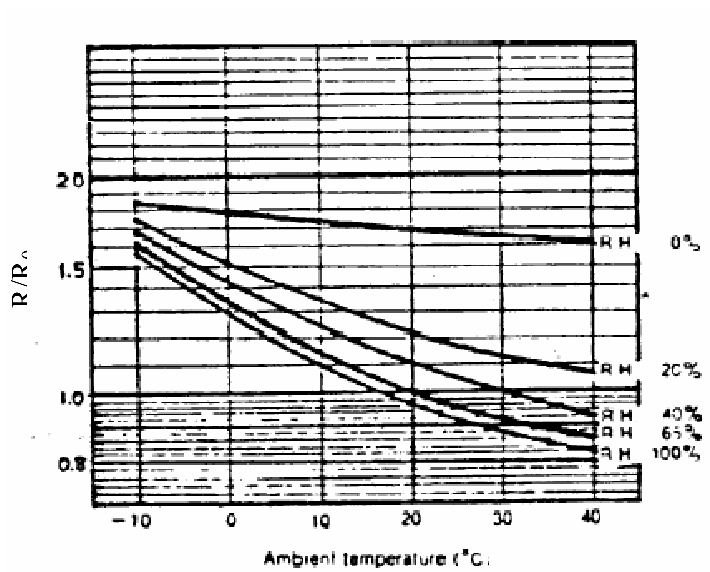

Figure 2
TGS#813 dependence on relative temperature and humidity

3 The Sensor´s Use

In Fig. 3 a basic gas concentration measure circuit is presented with sensor TGS#813.

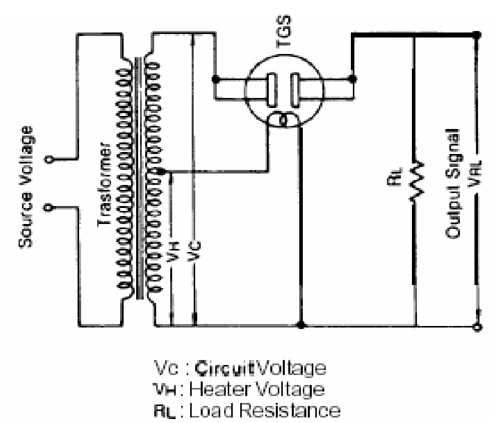

Figure 3
Measure circuit with TGS sensor

The fluctuation of the TGS sensor´s resistance is indirectly measured like the tension fall appeared on the reading resistance R_L. In working regime, the current, that passes through the sensor, which is serial with the R_L resistance, is constant, and if a gas like methane,butane, propane etc. comes in contact with the sensor´s surface, it´s endurance reduces in correlation with the present gas concentration. The tension fall on the R_L resistance is changing, so that together with the tension on the sensor the V_C value results, namely the continous supply tension (or altenative tension). As it follows, this sensor become very approchable for users because it has the exit in tension and it is very easy to mesure this parameter. To work with the features of the provided sensor, in this case, Figaro firm, we have to process this exit tension (V_{RL}) and to achieve the sensor´s endurance R_S with the ecuation (1):

$$R_S = \frac{V_C x R_L}{V_{RL}} - R_L \tag{1}$$

The configuration of the sensor´s connected circuits has to ensure the following conditions:

- V_C can be 5,6,12 or 24 V
- V_H heating tension has to be 5 V±0.2 V
- The power supply on the sensor maximum 15 mW

If we determine the sensor´s sensitivity feature in standard testing conditions, this characteristic has to coincide with the sensitivity feature, given to us by the producing Figaro firm, because this characteristic is determined with a relative representation of the sensor´s resistance.

Standard testing conditions, indicated by the producer, are:

- Atmospheric conditions: temperature 20 ºC±2 ºC and relative humidity 65%±5%
- V_C: 10 V±0.1 V, V_H: 5 V±0.05 V, R_L: 4 K±1%
- Time for the sensor´s supply maintenance 7 days or more
- Testing gas: methane

Sensor´s parameters:

- Heating resistance: 30 Ω±3 Ω
- Sensor´s resistance: 5 k ~15 KΩ methane 1000 ppm
- Resistance´s report: $\frac{R_S\, inmethane \quad 3000 \quad ppm}{R_S\, inmethane \quad 1000 \quad ppm} = 0.6 \pm 0.05$

Once the value R_0 is calculated, the sensor´s endurance at different concentrations of various gases will be next determined.

The sensor´s resistance for a given concentration is calculated as it follows. We admit the the snesor´s endurance at 1000 ppm methane is 10 KΩ and we want to determine it´s endurance at 4000 ppm hydrogen. From Fig. 1 arrises for R/R_0 the value 0.3, so it is only left for us to multiply 0.3 with 10 KΩ and we obtain that the sensor´s endurance value is 3 KΩ. Because we will supply the sensor´s heating circuit with a stabilised tension source, it is not relevant to discuss the influence of the supply (heating) tension´s variation on the sensor´s resistance. It is imposed to disuss about the influence of other parameters like temperature and relative humidity.

The determination of a gas´ concentration, if we want to eliminate the influence of temperature and relative humidity, is as it follows: with relation (1) we calculate R_S, then form Fig. 2, for temperature and relative humidity, we read the value R/R_0 in the given conditions and we obtain a value *x*. We multiply value *x* with R_0 and we obtain a value *y*. We divide R_S with *y* and we get $R/R_{0,}$ uninfluenced by temperature and relative humidity, with whose help, from Fig. 2, we will determine the appropiate concentration. The sensor´s features also depend on the working time period, like in Fig.4.

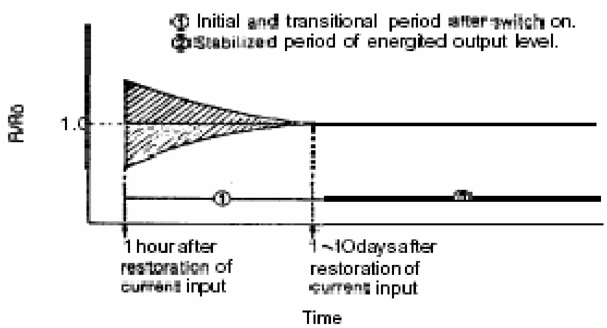

Figure 4
Dependența rezistenței senzorului TGS#813 de timpul de funcționare

When the snesor starts functioning, after a long not working period, a time interval has to pass until the sensor´s resistance reaches a stable regime. This time interval depends on the atmospheric conditions of the place the sensor was kept. It is important not to calibrate any of the circuits that contain this sensor (TGS#813), before the resistance stabilises, because we can obtain wrong results. A sensor´s lifetime is 8-10 years.[3].

The feature illustrated in Fig. 2 has to be approximated in order to make a very exact calculation of the temperature´s and relative humidity´s influence on the value of the ensor´s endurance.

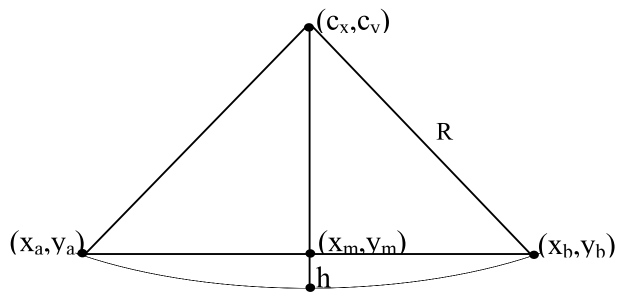

Figure 5 Approximation through arcs of circle

We try to approximate these curves on the feature through circle arcs. We detail on base of Fig. 5. We need the coordinates of the ending points (T, R/R_0) at –10 ºC, noted (x_a, y_a) and at +40 ºC, noted (x_b, y_b) and we also need another parameter, the arc´s height, noted *(h)*. At first, the coodinates (x_m, y_m) are established, through a simple calculation, with the formulas:

$$x_m = \frac{x_a + x_b}{2}, \; y_m = \frac{y_a + y_b}{2} \tag{2}$$

We determine the line's equation through the points (x_a, y_a), (x_b, y_b), which has the form:

$$y = a * x + b \tag{3}$$

values *a* and *b* are obtained with the relations:

$$a = \frac{y_a - y_b}{x_a - x_b}; b = y_b - x_b * a \tag{4}$$

We calculate the equation of the orthogonal line on the previous determined line that passes through the point (xm, ym), which if of form (3) with parameters a_1, b_1, which can be determined with the following relations:

$$a_1 = -\frac{1}{a}, b_1 = y_m - x_m * a_1 \tag{5}$$

We calculate the distance between (x_a, y_a), (x_b, y_b) noted *(dist)*:

$$dist = \sqrt{(x_a - x_b)^2 + (y_a - y_b)^2} \tag{6}$$

Having *dist* and *h* we can calculate the circle's radius, noted R_c, like this:

$$R_c = \frac{\left(\frac{dist}{2}\right)^2 + h^2}{2 * h} \tag{7}$$

Having this informations we'll determine [4] the coordinates of the circle's centre under the condition that it's radius is R_c and the centre located on the orthogonal line on the determined one by the points $(x_{a,}, y_a)$, (x_b, y_b), in the coordinates point (x_m, y_m):

$$(x - c_x)^2 + (y - c_y)^2 = R_c^2 \qquad (8)$$
$$y = a_1 * x + b_1$$

If we explicit c_y from the line's equation: $c_y = a_1 * c_x + b_1$ (9) and replace it in The circle's equation, we obtain the second degree equation:

$$(1+a_1^2)*c_x^2 + 2*(a_1*b_1 - y*a_1 - x)*c_x + y^2 + x^2 - 2*y*b_1 + b_1^2 - R_c^2 = 0 \qquad (10)$$

With the condition that the equation (10) has to contain the point (x_a, y_a), the equation becomes:

$$(1+a_1^2)*c_x^2 + 2*(a_1*b_1 - y_a*a_1 - x_a)*c_x + y_a^2 + x_a^2 - 2*y_a*b_1 + b_1^2 - R_c^2 = 0 \qquad (11)$$

We determine from this equation c_x with the relation:

$$c_x = \frac{-(a_1*b_1 - y_a*a_1 - x_a) + \sqrt{(a_1*b_1 - y_a*a_1 - x_a)^2 - (1+a_1^2)*(y_a^2 + x_a^2 - 2*y_a*b_1 + b_1^2 - R_c^2)}}{(1+a_1^2)} \qquad (12)$$

As a last step we calculate c_y with the relation (9).

Having the circle's equation, radius and center's coordinates we can easily calculate for any temperature and relative humidity, with which we have made the determinations, the sensor's resistance value compared to normal conditions.

Misfortunately, this calculation is for a certain value of the relative humidity, but in the main this is how the circle's parameters are determined, having the coordinates of the two points and the arc's height.

We still haven't solved the problem because we have to make the calculation for the relative humidity. This is made tabling. Each curve's parameters for a certain relative humidity and then these parameters will be approximated in accordance to the relative humidity with a third degree equation. But let's see these parameters, Table 1.

RH	H	y_a	y_b
0	0.01	1.83	1.6
20	0.08	1.73	1.07
40	0.12	1.68	0.92
65	0.15	1.6	0.86
100	0.18	1.57	0.82

Table 1
Parameter's values at different values of relative humidity

In Figs. 6 and 7 we have the approximations of these parameters with third degree equations, together with the original curve. The approximation was made in EXCEL , this is why when we work with approximation equation instead of *x,* we have to use an adjusted value, namely the interval [0;20] ->[1;2] ; (20;40] ->(2;3]; (40;65]->(3;4]; (65;100] ->(4;5].

With the help of these approximation equations, we can calculate for a value of relative humidity the parameters *h,* y_a and y_b. Knowing that x_a=-10 °C and x_b=+40°C, we can always establish the circle's parameters with the relations (1)÷(10), which has as the arc, the respective curve and we can make the calculation.

The calculation procedure is the following:

- For the relative humidity value we determine y_a,y_b,m
- We establish with these values the circle's parameters
- For the temperature value we determine R/R_0"
- We calculate R with the relation (1) and we divide with R_0 obtaining R/R_0

$R/R_0 = \frac{R/R_0}{R/R_0"}$ (13) With this value we can go to the sensitivity feature and calculate the concentration for the desired gas, taking into consideration that it is a logarithmic feature.

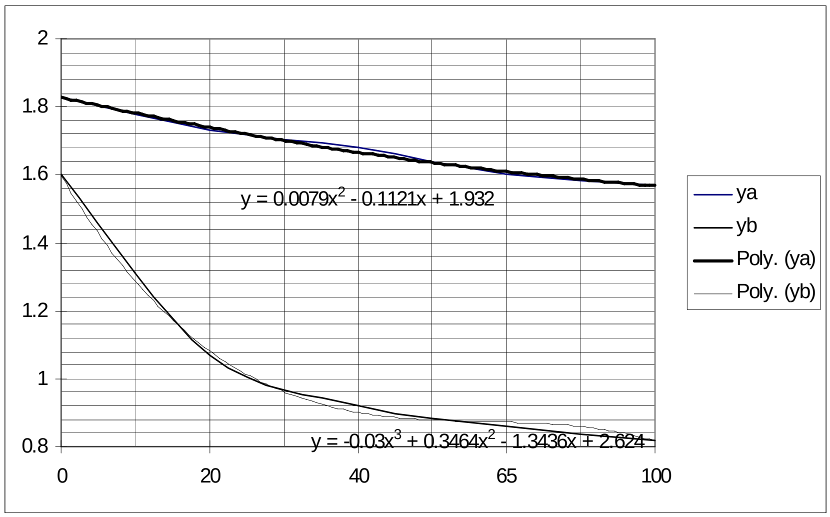

Fig. 6. Coordinates y_a,y_b depending on the relative humidity

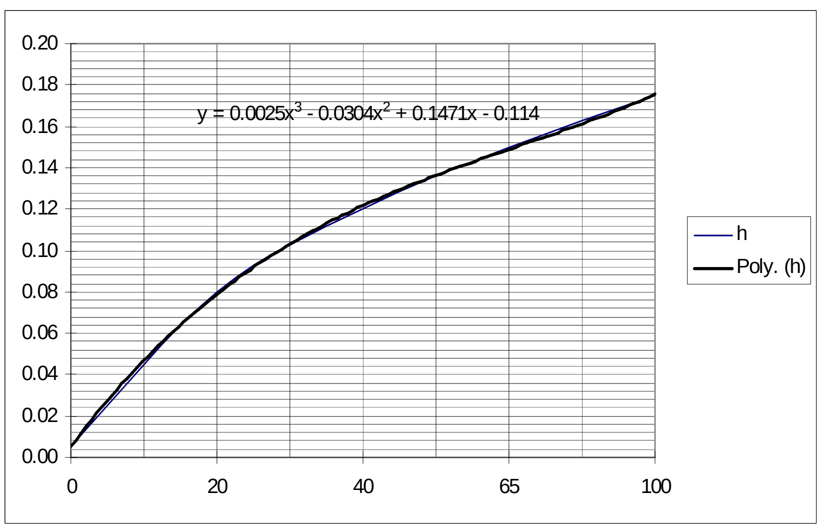

Fig. 7. The height of the circle´s arc *h*, dependeing on the relative humidity

If we implement the characteristic relative resistance – temperature – relative humidity with a two dimensional search table, then we will have Table 2.

T/RH	0	10	20	30	40	50	60	70	80	90	100
-10	1.83	1.781	1.74	1.7011	1.6668	1.6422	1.6201	1.6031	1.590	1.5791	1.569
-5	1.803	1.7143	1.644	1.5899	1.5461	1.5169	1.4912	1.471	1.455	1.4392	1.4234
0	1.7784	1.651	1.556	1.4869	1.4352	1.4025	1.3744	1.352	1.333	1.3141	1.2935
5	1.7543	1.5917	1.4747	1.3922	1.3341	1.2991	1.2696	1.246	1.225	1.2038	1.1792
10	1.7306	1.536	1.399	1.3058	1.2428	1.2066	1.177	1.1531	1.132	1.1083	1.0805
15	1.7073	1.4848	1.33	1.2277	1.1614	1.125	1.0963	1.0732	1.052	1.0275	0.9974
20	1.6844	1.437	1.268	1.1579	1.0897	1.0544	1.0278	1.0064	0.986	0.9616	0.93
25	1.662	1.394	1.212	1.0963	1.0277	0.9946	0.9713	0.9527	0.934	0.9103	0.8781
30	1.64	1.354	1.1623	1.043	0.9756	0.9458	0.9268	0.912	0.896	0.8739	0.8418
35	1.62	1.318	1.119	0.998	0.9333	0.908	0.8945	0.8844	0.872	0.8522	0.8211
40	1.6	1.28	1.0824	0.961	0.9008	0.881	0.8741	0.8698	0.861	0.8452	0.816

Table 2

Search table for the characteristic relative resistance – temperature – relative humidity

As a columns index we have the samples of relative humidity from 10% to 10%, as rows index the temperature samples from 5 °C to 5 °C, and as value in the table we'll have relative resistance. There are problems concerning the edge only in temperature case and because of this fact we express the following rules:

- if the temperature is lower than -10°C, then it is considered as if it would be in the interval [-10 °C, -5 °C]
- if the temperature is higher than +40°C, then it is considered as if it would be in the interval [+35 °C, +40°C]

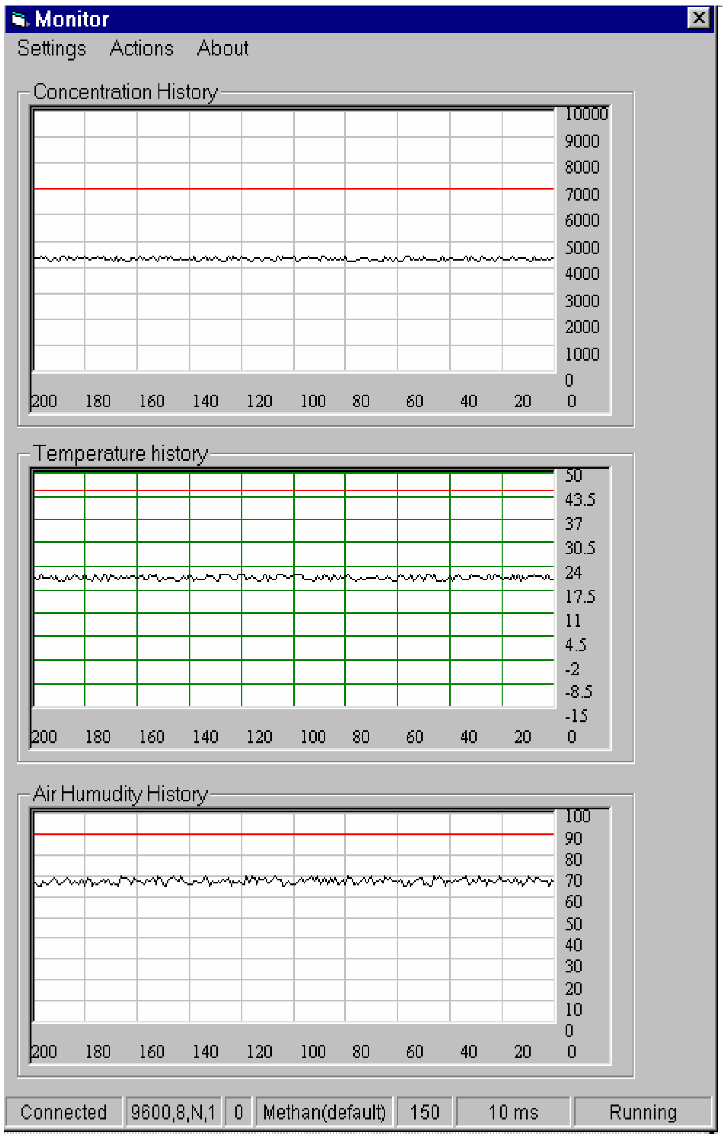

Figure 8. The measurement results

As an implementing algorithm, at first we determine in which intervals are temperature and relative humidity located, considering previous reasons and we choose the four points, which mark these intervals. We'll have four triples for example for *RH*=75%, *T*=12 °C:

(*10,70,Ta[indt,indrh*]), (*10,80,Ta[indt,indrh+1]*),

(*20,70,Ta[indt+1,indrh]*), (*20,80,Ta[indt+1,indrh+1]*),

where indt=T<-10?0:T>=40?9:floor((T+10)/5); indrh=floor(RH/10); Ta – search table. The relative resistance value will be calculated with relation (14).

$$R / R_0 = \frac{(T - indt * 5 - 10)}{5} * (Ta[indt + 1, indrh] - Ta[indt, indrh]) + + \frac{(RH - indrh * 10)}{10} * (Ta[indt, indrh + 1] - Ta[indt, indrh]) + Ta[indt, indrh] \quad (14)$$

Applying the facts presented it can proceed to the software implementation of the gas ´ concentration sensor´s features.

Conclusions

The obtained results, applied to a measuring system carried out with such a sensor are illustrated in Fig. 8. Methane concentration, temperature and humidity at the measure place are presented.

In the paper, the temperature's and humidity's influence is emphasized – when a precise measure of a gas´ concentration is desired – and there are elaborated the relations through which the parameters are taken into consideration, but also how they can easily be implemented in embedded systems [5]. It facilitates the use of these sensors in dedicated air gas measuring systems, realised with the help of microcontrollers. It appears the possibility to monitories more measuring points with dedicated systems, using the internet.

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