

Flexible Gas Detector

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Abstract: A version of gas detector using market sensors, as well as sensors developed in Yerevan State University is proposed (all sensors are resistive type). The main goal is to obtain a system model and a prototype based on it. The system is composed of both analog and digital parts.

Keywords: gas detector, resistive sensors, flexible hardware, microcontroller.

1. Introduction

Semiconductor sensors are developed in Yerevan State University (Armenia) for the following gases: Acetone, Ammonia, Benzene, Butanol, i-butane, Dichlor ethane, Dimethyl formamide, Ethanol, Formaldehyde, Gasoline, Humidity, Hydrogen, Hydrogen peroxide, Iperit, Methanol, Natural gas, Nitrogen oxides, Propylene glycol, Smoke, Sulfurous anhydride, Sulfurous oxides, Toluene, Zarine etc [1-7]. Some of such gas sensors (except chemical warfare, some toxic and market sensors, gas sensors) are produced in the USA, Japan, China, Russia and Germany. YSU sensors cost less, have smaller sizes, lower working temperature and higher sensitivity. Independent testing of sensors in the USA and Czech Republic showed promising results.

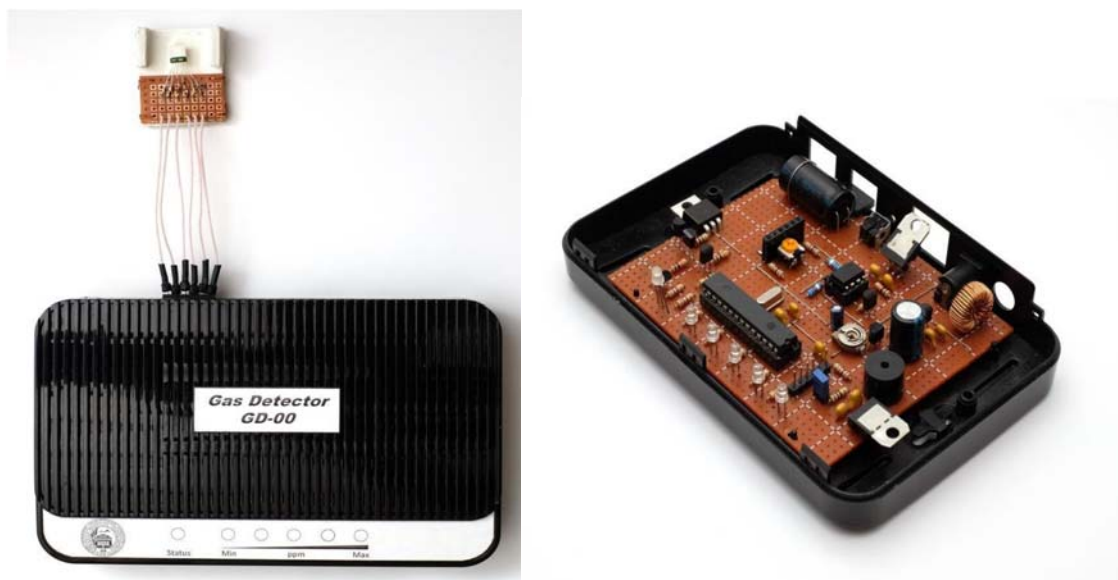


Figure 1: The prototype detector. On the left, the detector is shown in its case connected to the sensor from outside. On the right, the internal part of the detector is shown.

We developed a version of a gas detector using the above-material sensors. All our sensors are of resistive type. Their electrical resistance is remarkably changed when the sensor contacts with the gas. It is a device with flexible hardware and software parts, which will enable to measure and illustrate the parameters of the resistive semiconductor gas sensors, as well as to process those parameters and, if needed, notify about any surpass of the acceptable limit of concentration. By saying flexibility, we mean that there will be no need to change the hardware of the device to be able to work with different sensors. Instead, one will only need to insert adjustments in the software and that will be enough. It will help decrease expenses and work with large markets.

An experimental prototype (see Figure 1) has been created as the initial version, and the results can be considered as satisfying. Naturally, a few drawbacks have also been noted, which have been studied and will be resolved during the making of the new prototype.

The constructed prototype is powered by DC 12V voltage supply from the network. It uses a maximum of 300mA current. A middle-class of PIC microcontrollers from Microchip Company is used as the brain of the device. The measurements are calculated by the microcontrollers ADC itself, the temperature adjustment by the pulse width modulation (PWM). Using Bluetooth, the device sends the sensor's measured parameters to the smartphone via a special written software. It shows time-dependence of resistance on the screen. The observational error $\sim 0.4\%$. It is expected to decrease the electricity usage which will enable to power the device from an accumulator, making it portable, as well as decreasing the observational error up to $\sim 0.02\%$. Further steps will be taken towards making the analog circuits power supply more manageable.

In the future, it will be possible to create an automated research device. Attaching a gas tank and an appropriate software for PC to the given device, we will have a renewed device which will enable us to received, for instance, the sensor's resistance and the dependence of the target gas concentration.

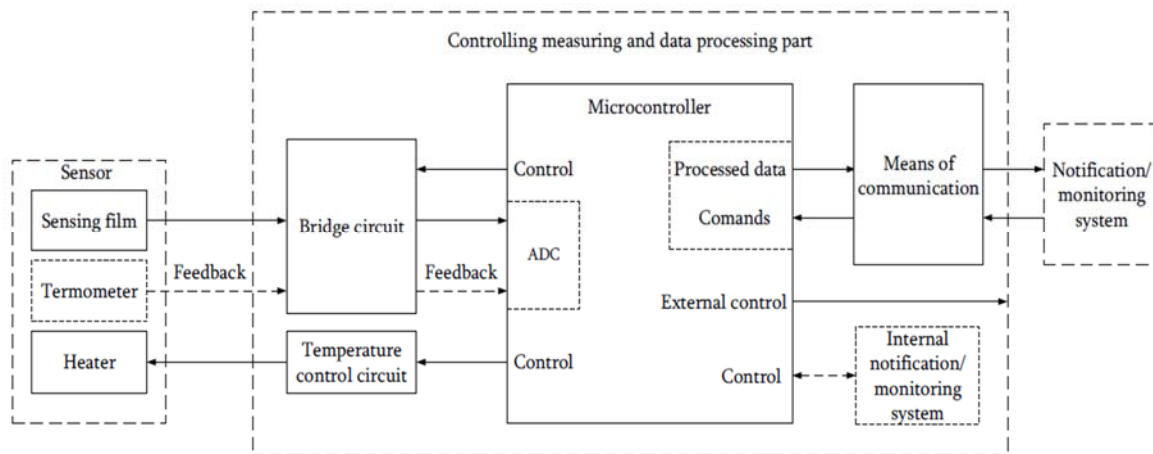


Figure 2: System block diagram. Thermometer and therefore also the feedback parts could be missing for some gas sensors. That is why they are drawn in dotted lines. Internal notification/monitoring system is also conditional.

2. System Structure

In general, the structure of the system consists of ;

- sensors
- controlling, measuring and data processing part,
- notification and/or monitoring device.

The controlling, measuring and data processing part is designed to keep constant temperature of the sensor's sensing part and measures the resistance of the latter. After that it sends the processed data to notification and/or monitoring part to change the parameters of the system or give some instructions to it.

The notification and/or monitoring device can not only be separated but also built in the controlling part or connected using USB, RS-232 etc. Otherwise, they can connect with each other wirelessly , as mentioned before, using Bluetooth to connect directly, or Wi-Fi using the web. In Figure 2 you can see the whole system structure with some internal detailed blocks.

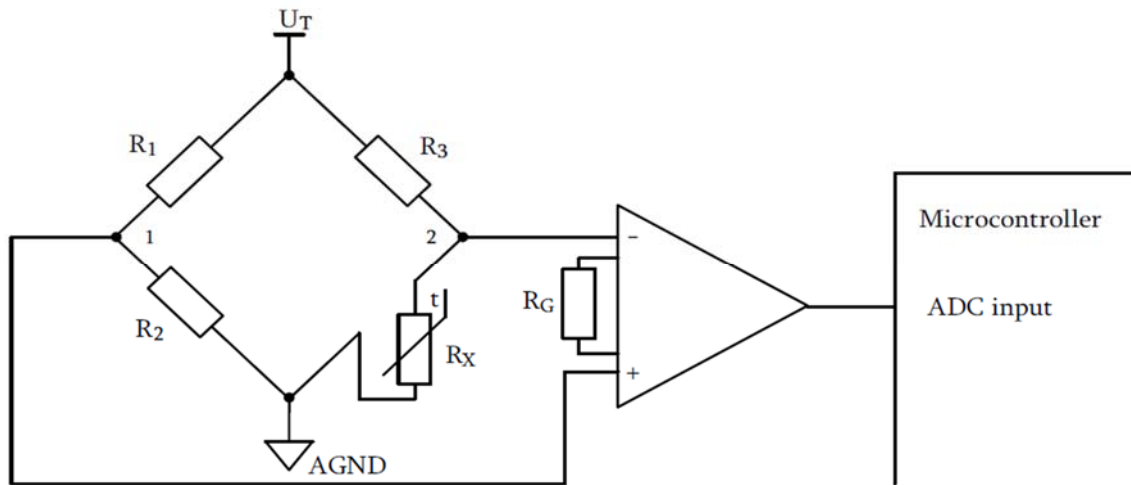


Figure 3: Bridge circuit. R_x is a resistive thermometer and R_G is a gain resistor.

2.1. Temperature Control

Usually, most of the gas sensors have fixed working temperature and, therefore, an in-built heater. The most simple and convenient way to control heating power is PWM. Modifying duty cycle of the PWM, it is easy to adjust the temperature of the sensing film. Besides, almost all microcontrollers have an inbuilt PWM module. With the help of the logic level MOSFET it is easy to organize it. If the Sensor has an inbuilt thermometer , it will make the temperature adjustment more precise. In Figure 3, the bridge circuit is show which allows to measure the temperature using a resistive type of thermometer. Calculating voltage differences between 1 and 2 points and knowing the resistance values of R_1 , R_2 and R_3 it is easy to calculate R_x to now the temperature.

It is important to use resistor with high precision. To calculate voltage difference between 1 and 2 points, an instrumentation amplifier can be used. The output of the amplifier is connected to the ADC input of microcontroller. In this case, for R_x we have this formula;

$$R_x = \frac{R_3 \left(R_2 - R_G \frac{U_{1,2}}{U_T} (R_1 + R_2) \right)}{R_1 + R_G \frac{U_{1,2}}{U_T} (R_1 + R_2)}. \quad (1)$$

where R_G is a gain resistor of amplifier, U_T is a constant voltage supply for bridge circuit and $U_{1,2}$ is a voltage difference between 1 and 2 points. The formula is easy to implement into the microcontroller code for temperature control.

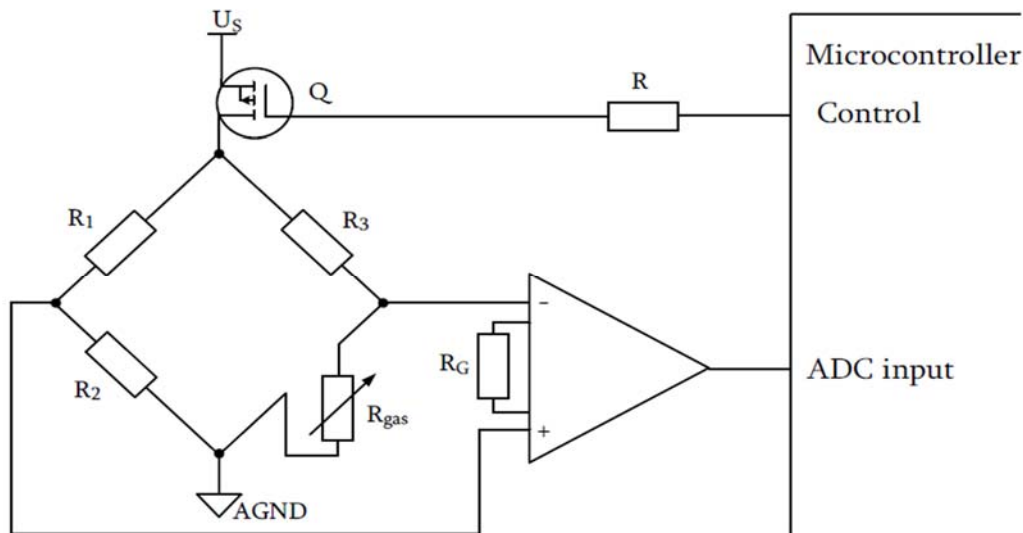


Figure 4: Bridge circuit R_{gas} is a sensing film, R_G is a resistor and Q is MOSFET to control the flow of current thru the circuit.

2.2. Measuring Resistance of Sensitive Film

To measure the parameters of the sensor, in our case – the resistance, the same scheme has been used to measure the temperature. Only with one difference: logic level MOSFET has been added to control the current flow to the bridge circuit (see Figure 4). Lot of gas sensors' sensing film can be damaged because of the continuous current flow through it, and turning on and off the MOSFET key, the system can let the current flow only after it has taken a sample measurement. It also makes the system work with larger spectrum of gas sensors.

The formula for R_{gas} will be the same;

$$R_{gas} = \frac{R_3 \left(R_2 - R_G \frac{U_{1,2}}{U_s} (R_1 + R_2) \right)}{R_1 + R_G \frac{U_{1,2}}{U_s} (R_1 + R_2)}. \quad (2)$$

We can ignore the resistance of the opened transistor ($\sim 0.02\Omega$) because it will be endless small compare with resistors ($\sim 1K - 10M\Omega$) used in the bridge circuit. It is important to note that in the system we have two types of circuits: analog and digital. It means that digital circuit will make high frequency noises and it will affect the digital part and give false values to the shown parameters. To solve this, low pass filters have been used in analogue circuit parts.

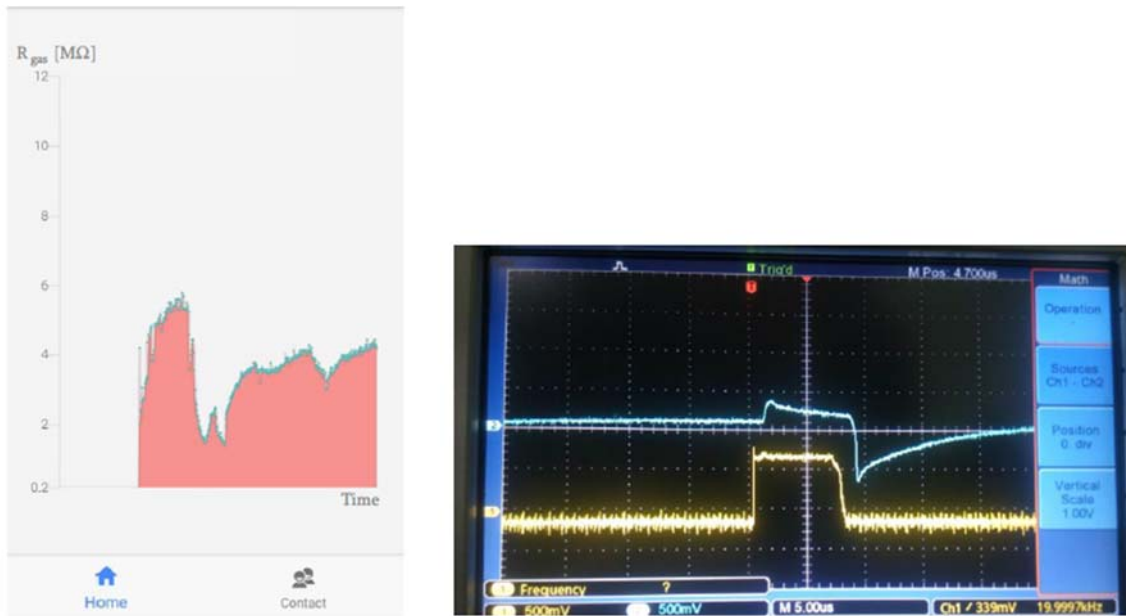


Figure 5: On the left a screenshot of the smartphone program is shown. On the right, an oscilloscope screen photo is shown; the yellow line is a voltage drop on the heater and the blue line is the temperature scheme.

3. Results

Prototype and smartphone software tests have been conducted for research. Devices have been connected via Bluetooth. On the left (Figure 5) a screenshot of beta version of the program is shown in work and it has been taken during the tests to check the system work. Here we can see the sensor response to the alcohol vapor. The resistance decreases and then goes back when it is removed.

For these tests, gas sensors made in YSU have been used. As a bulk of sensor, Multi-Sensor-Platform KBI2 from TESLA BLATNA has been used. The platform integrates a temperature sensor ($Pt1000$), a heater and interdigitated electrode structures (IDES) in platinum thin film on a ceramic substrate.

During the tests one issue has been discovered. It is connected to the way of heating the sensor. The yellow waveform (on the right, Figure 5) demonstrates a voltage drop on heater, and the blue one is an output of instrumentation amplifier of temperature scheme. In the rising and falling edges of PWM the temperature gets distorted in a very short time, about $10^0 C$ and it causes distortions on the sensing film. This problem can be solved by adding a circuit step down converter in the heater, supply the heater by it and control the output of it via PWM.

4. Conclusion

The main goal has been successfully reached. The test of the prototype shows sufficient results, it shows that the system model works, also it shows in which parts it has issues. This architecture can be used to design devices for larger markets, starting from everyday life usage up to monitoring systems for factories, for military purposes and as a measuring system for science research.

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