Air Quality Monitoring System

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AIR QUALITY MONITORING SYSTEM

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Detection of low concentration of air pollution, like cigarette smoke, cooking fumes, etc. is possible with the combination of an air quality sensor and data acquisition system. In present paper is presented approach for design and implementation of air quality monitoring system based on tin dioxide gas sensor, integrated temperature and humidity sensors, portable modular data acquisition system and graphical programming language. An interpolation method reducing influence from temperature and humidity is suggested. This approach can be used for automatic controls in ventilation systems by detecting rapid changes in the air quality from the base levels.

Keywords: Air Contaminants Detection, Logging and Monitoring Systems, Portable USB DAQ, Taguchi Gas Sensors, Virtual Instrumentation.

1. INTRODUCTION

To provide adequate environmental and health protection, an effective air quality monitoring system is a necessary instrument. It is desirable that the system is simple, reliable, sensitive and cost-effective. In addition this system must be high sensitive to low concentrations of gaseous air contaminants such as hydrogen and carbon monoxide which exist in cigarette smoke. The current trend for air contaminants monitoring and alarm systems development is to increase the sensitivity and to reduce the response time, in particular at low air contaminants concentrations.

Typical environmental sampling methods for these contaminants employ manual grab samples that are collected on site and then transported to a laboratory for analysis. These sampling methods can be very costly and time consuming, and ongoing research has focused on the development of sensors that can replace traditional sampling methods to monitor contaminants in the environment.

Gas sensor based on semiconducting materials have become of great interest to both sensor users and researchers. In this context, a huge number of publications have appeared in the literature which deals with metal oxide gas sensors, in general, and with the prototype material tin dioxide, in particular [3].

To monitor temperature and humidity of the air it is suitable to use the recently appeared new integrated sensors. These sensors have on-chip temperature compensation and calibration, an amplifier signal conditioning that allow interface directly to any microcomputer with an on-board analog to digital converter (ADC). Usually the integrated sensors translate the physical quantity into a 0.5 to 4.5 volt output range that is designed to be directly compatible with ADC inputs of data acquisition systems (DAQ) [6, 7].

In present paper the investigation of tin dioxide gas sensor for air contaminants is introduced. Based on such semiconducting sensor, supported by temperature and humidity integrated sensors, the design and implementation of virtual system for air quality monitoring is suggested.

2. TIN DIOXIDE GAS SENSORS

Tin dioxide sensors are widely used for the detection of air contaminants such as carbon monoxide, methane, hydrogen, iso-butane etc. Metal oxides have attracted the attention of many users and scientists interested in gas sensing under atmospheric condition. In spite of extensive activities world wide in the research and development of these sensors, scientific understanding of practically useful gas sensor is very poor [3]. Tin dioxide sensors are the best-understood prototype of oxide-based gas sensors. Nevertheless, highly specific and sensitive tin dioxide sensors are not yet available. It is well known that sensor selectivity can be fine-tuned over a wide range by varying the oxide crystal structure and morphology, dopants, contact geometries, operation temperature or mode of operation, etc. The understanding of real sensor signals as they are measured in practical application is hence quite difficult.

2.1 Gas detection principle

A solid-state (so called Taguchi) sensor consists of one or more metal oxides from the transition metals, such as tin oxide, aluminum oxide, etc [3]. There are different ways of making solid-state sensors, each arrangement making the sensor's performance characteristics different. These metal oxides are prepared and processed into a paste which is used to form a bead-type sensor. Alternatively, thick or thin film-chip sensors are made when the metal oxides are vacuum deposited onto a silica chip, in a fashion similar to making semiconductors. A heating element is used to regulate the sensor temperature, since the finished sensors exhibit different gas response characteristics at different temperature ranges. This heating element can be a platinum or platinum alloy wire, a resistive metal oxide, or a thin layer of deposited platinum. The sensor is then processed at a specific high temperature which determines the specific characteristics of the finished sensor [6].

In the presence of gas, the metal oxide causes the gas to dissociate into charged ions or complexes which results in the transfer of electrons. The built-in heater, which heats the metal oxide material to an operational temperature range that is optimal for the gas to be detected, is regulated and controlled by a specific circuit.

A pair of biased electrodes is imbedded into the metal oxide to measure its conductivity change. The change in the conductivity of the sensor resulting from the interaction with the gas molecules is measured as a signal. Typically, a solid-state sensor produces a very strong signal, especially at high gas concentrations.

2.2 Figaro Gas Sensors 2600 Series

The FIGARO 2600 [1, 2, 4] series is a new type thick film metal oxide semiconductor, screen printed gas sensor which offers miniaturization and lower power consumption (less then 225 mW). The TGS26xx displays high selectivity and sensitivity to low concentrations of various air contaminants such as combustible gases (butane – TGS2610; methane and natural gas – TGS2611; methane and carbon monoxide – TGS2670) or solvent vapors (alcohol and organic solvents – TGS2620).

For detection of air contaminants most appropriate is TGS2600 [1]. The main features of the TGS2600 sensors are high selectivity to low gas concentrations, low power consumption, small size and long life. They have many applications like air cleaners for indoor air; air cleaners for vehicles; air quality monitors; Heating, Ventilating and Cooling (HVAC) system etc.

3. DESIGN AND IMPLEMENTATION OF VIRTUAL SYSTEM FOR GAS MONITORING

The goal of the designed virtual system is to acquire, process, archive and transmit the required signals, as well as to build automatic visualization reports, that can be used by any person for easy observing of air quality.

The developed system can be observed as consisting of three main parts – a set of detectors (integrated and gas sensors), data acquisition system and graphical application development environment.

3.1 Sensing elements of the virtual system

Integrated sensors for measuring the physical phenomena (humidity and temperature) are selected according they readily available voltage output signals. To acquire the generated signals it is good practice all software and hardware to be based on open standards and readily expandable. They also wanted to have in-house autonomy to manage the system. To create virtual system for air quality monitoring, the following sensors are chosen:

- Integrated Relative Humidity Sensor HIH-3610 by Honeywell;
- Integrated Temperature Sensor AD22100 by Analog Devices and
- Tin dioxide gas sensor TGS2600 by FIGARO [1, 2].

3.2 Multifunction data acquisition system

The second component of the designed virtual system is a modular DAQ. The multifunctional DAQ boards perform a variety of tasks, including analog measurements and generation, digital measurements, and timing I/O. Using well-designed software drivers for modular DAQ, the engineers can quickly access functions during concurrent operation.

For the measuring part of the virtual system reported here, the National Instruments' multifunctional DAQ USB-6009 is used. This is a part of new generation of portable low-cost modular DAQ, controlled by computer via USB. The NI USB-6009 provides connection to eight analog input (AI) channels, two analog output (AO) channels, 12 digital input/output (DIO) channels, and a 32-bit counter with a full-speed USB interface. It ships with one detachable screw terminal block for analog signals and one detachable screw terminal block for digital signals. The connection between integrated sensors, gas sensor and DAQ is shown in fig. 1.

In the right part of the figure 1, the basic measuring circuit of gas sensor is shown. Circuit voltage (V_S) is applied across the sensor element which has a resistance (R_S)

between the sensor's two electrodes and the load resistor (R_L) connected in series. DC voltage is always required for the circuit voltage, and the polarity shown in fig. 1 must be maintained [2]. The sensor signal (V_{out}) is measured indirectly as a change in voltage across the R_L. The R_S is obtained from the formula $R_S = \frac{V_S - V_{out}}{V_{out}} R_L$.

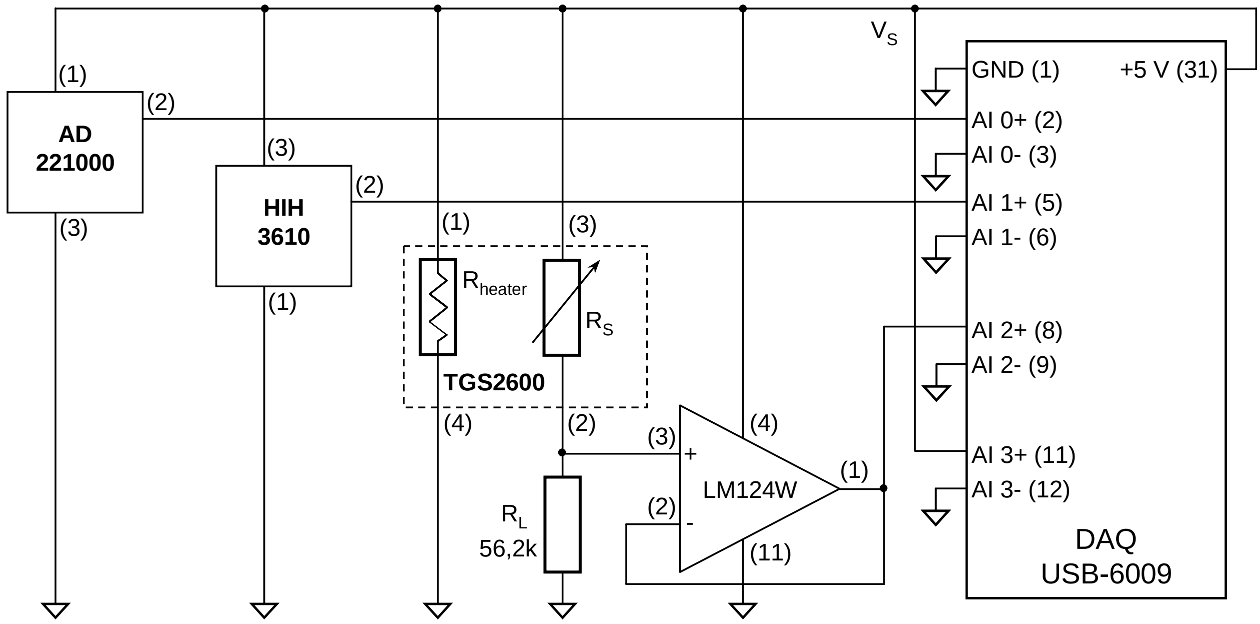

Fig. 1 Connections of integrated sensors and gas sensor to DAQ

With pure air R_S is high. With the presence of detectable gases, R_S changes with the variation of gas concentration. Since V_S is a fixed voltage, by measuring the voltage on the resistor R_L, the change on R_S as well as the gas concentration can be calculated. Pins 1 and 4 are connected to the heater of the sensor, and the resistance between them is designated as R_{heater}. The working temperature is as high as 400 ^{o}C.

Analog input channels are configured for differential measurements. As the impute impedance of DAQ is low (144 kΩ), but the output signal of the gas sensor is large enough, the interface circuit uses only a voltage follower as a buffer between the gas sensor output and the ADC. Additionally, this approach makes the system less sensitive to external interferences.

3.3 Application development environment

It is well known that the heart of any virtual instrument and system is the flexible software [6, 7]. One of the world's best virtual instrumentation software platforms is National Instruments LabVIEW. This graphical development environment offers the performance and flexibility of a programming language, as well as high-level functionality and configuration utilities designed specifically for measurement and automation applications. The LabVIEW provides an intuitive interface for designing custom virtual instrumentation systems. LabVIEW is chosen as the development software not only because of its unique capabilities to acquire, process, and manipulating data, but also because it has the required data visualization capabilities.

The general technical specification of designed and implemented virtual system is briefly shown in table 1.

Table 1. The general specifications of the virtual system

	Model	Range	Accuracy (FS)	Power consumption
Relative Humidity	HIH 3610 (Honeywell)	0 ÷ 100 %	± 2 %	0.2 mA
Temperature	AD 22100 (Analog Devices)	- 50 ÷ + 150 °C	± 2 %	0.65 mA
Air Contaminants	TGS 2600 (FIGARO)	1 ÷ 100 ppm concentration	2 ppm	50 mA
Data Acquisition System	NI USB-6009	4 differential AI Channels 14 bit resolution; Input impedance 144 kΩ; +5 V/ 200 mA Output Voltage		
Software	LabVIEW v. 8; NI-DAQmx v. 8			

4. TEMPERATURE AND HUMIDITY COMPENSATION OF THE GAS SENSOR

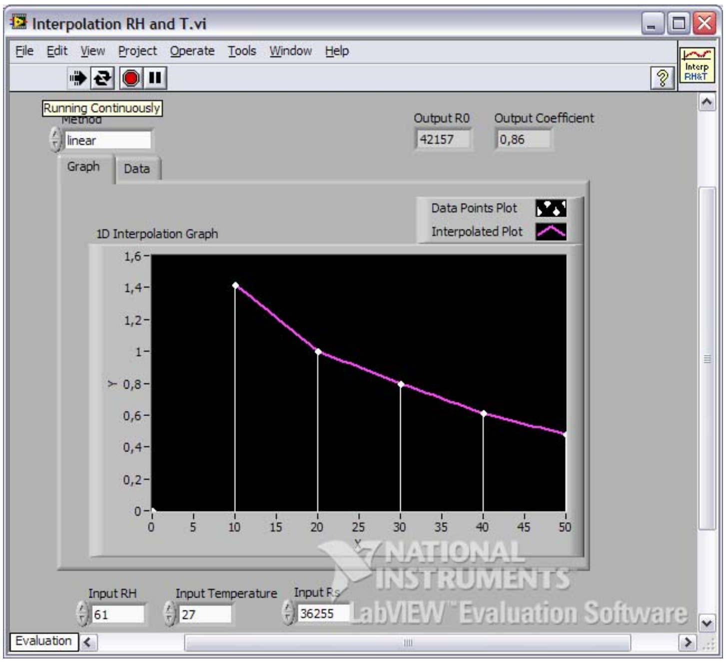

Fig. 2. The front panel for temperature and humidity compensation

As is mentioned above the detection principle of TGS sensors is based on chemical adsorption and desorption of gases on the sensor's surface. As a result, ambient temperature will affect sensitivity characteristics by changing the rate of chemical reaction. In addition, humidity causes a decrease in resistance as water vapor adsorbs on the sensor's surface. A compensation circuit or method for temperature and humidity dependency should be considered when using TGS sensors. The datasheets demonstrates [2] that, when used in the range of 10°C~50°C, sensitivity in air shows temperature and humidity dependency. As a result, temperature and humidity compensation for the sensor must be done for fresh air values.

In the present paper a compensation method based on capabilities of virtual instrumentation is suggested. The method consist of one-dimensional interpolation using a selectable tables fulfilled with data given in sensor's datasheet. The custom created software accepts measured temperature and humidity and provides interpolated value corresponding to correction coefficient. The front panel of created software for temperature and humidity compensation is shown in figure 2.

5. EXPERIMENTAL RESULTS

Figure 3 shows the front panel of the designed virtual system for air quality monitoring. The front panel consists of three vertical graduated bars. The first one is placed in the left side and display the air temperature. The next bar (in the middle of the panel) visualizes the current moisture. The last one is located in the right of the front panel and corresponds with the relative air contaminants. The bar-diagram shows the ratios of the measured sensor resistance R_S to the sensor resistance in clean air R_0 with appropriate corrections according to the current temperature and humidity conditions.

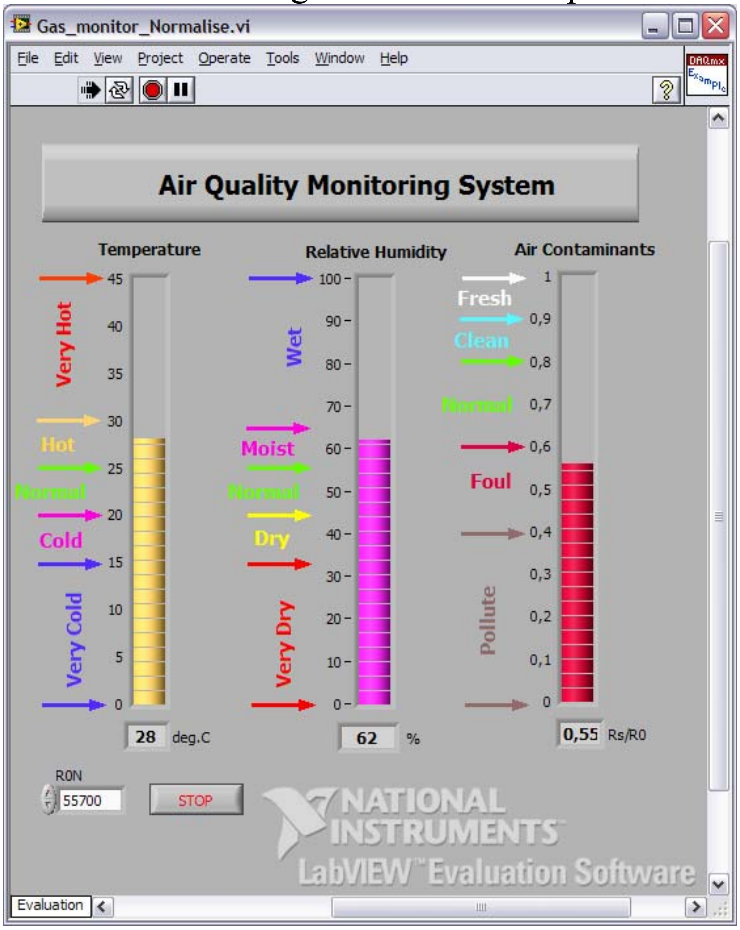

Fig. 3. The front panel for air quality monitoring

Data shown in figure 3 was taken in a 36 m^3 room with one cigarette placed on a flat surface. The burning time for the cigarette (Orient Express) is approximately 7 minutes. Generally, the activation point for an air cleaner would be around $R_S/R_0 = 0.85$, [4] while it for just one cigarette is as low as 0.55, making this system ideal for air cleaner application.

6. CONCLUSION

In the present paper, the design of a virtual system for air quality monitoring has been discussed. The system has been designed and built using tin dioxide gas sensor, integrated sensors, portable modular DAQ and graphical software LabVIEW. The developed virtual system is portable and affordable since it is small and inexpensive. Presented system is convenient especially for those engineers and students for which the DAQ cards are available. Therefore, the effort made in designing a system leads toward a new direction of methods for enhance indoor environmental quality in the future. The experimental results show that the monitoring system has good sensitivity to low concentrations of air contaminants, including those found in cigarette smoke. This investigation has been carried out in the framework of the research project 790-ПД-3/2006.

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