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Automotive Requirements for Sensors using Air Quality Gas Sensors as an Example

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Abstract

This work outlines the requirements of sensors for use in automotive applications and describes the features of automotive air quality gas sensors as an example. Implementing these sensors in an automotive environment poses a number of challenges, due to the wide range of possible temperature, atmospheric pressure, humidity and vibration profiles. Additionally, the sensors are required to fulfill substantial reliability, quality and cost requirements. Based on the example of a metal oxide semiconductor gas sensor the technical specification and the qualification criteria for automotive capability are presented.

Keywords: Automotive Requirements; Sensors

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1. Introduction

The demands on automotive sensors are divided into electrical, mechanical, climatic and chemical requirements that depend on the electrical load and positioning conditions in the vehicle. The example given here describes an air quality sensor that is connected via the LIN bus to the vehicle electrical system and is positioned in the engine compartment of the vehicle. This sensor measures the ambient air quality in order to control the recirculation flap of the vehicle's Heating, Ventilation and Air Conditioning (HVAC) system. The sensor provides an output signal corresponding to the gas concentration of the prevalent pollutant and the degree of odor contamination. To analyze the air quality outside the vehicle cabin, sensors based on the change in conductivity of metal oxide semiconductors are primarily used. The advantages of metal oxide semiconductor sensors are their high sensitivity for the gas to be detected, low dependence on humidity and temperature, long service life, and relatively low production costs. Due to a sensitivity drift with increasing life span and limited technological reproducibility of the sensor properties, metal oxide gas sensors are mainly used to measure relative changes in concentration [1] as occurring in the detection of air quality changes. The operation of metal oxide gas sensors is based on the change in conductivity of a metal oxide semiconductor under the influence of reducing or oxidizing gases. The design of a metal oxide gas

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sensor in micro-structured silicon technology and the cross section of a typical automotive air quality gas sensor are illustrated in Fig. 1. As gas-sensitive materials, metal oxides such as SnO_2, ZnO or WO_3 are mainly used. The gas-sensitive metal oxide layer is contacted by a structured metallization, for example made of platinum. The metallization and the gas-sensitive layer are electrically isolated from the heating layer (e.g. platinum meanders) by a passivation.

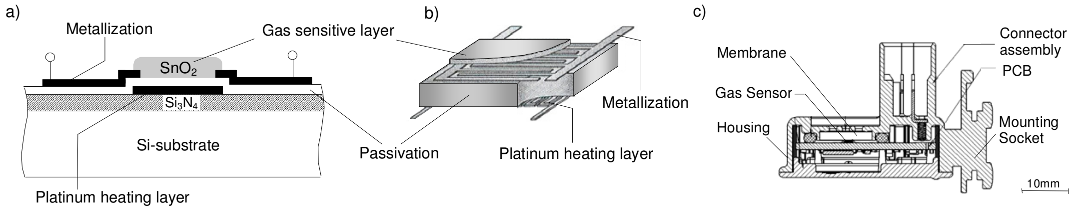

Fig. 1: Schematic illustration of a micro-structured metal oxide gas sensor (a) cross section; (b) metallization as inter-digital structure, and heating layer as platinum meander structure; (c) cross section of a typical automotive air quality sensor with embedded metal oxide gas sensor

Reducing gases (e.g. CO, C_xH_y) result in an increase in conductivity; oxidizing gases (e.g. O_2, NO_2) produce a reduction in the conductivity of the metal oxide. For the detection of various directing gases, several sensor elements are combined. Their associated output signals are conditioned to a classified sensor output signal of so-called air quality levels as a pulse-width modulated signal or LIN output. Table 1 gives an overview of the technical specification of a standardized LIN-based air quality gas sensor [2].

Table 1. Technical specification of standardized air quality gas sensor [2]

Property	Value
Sensitivity 1st Gas (CO)	< 1ppm
Sensitivity 2nd Gas (NO_2)	< 50ppb
Cross sensitivity	Small
Contamination	None
Response time t_{90}	< 1s
Ambient temperature ϑ_A	-40°C ≤ ϑ_A ≤ 85°C
Storage temperature ϑ_S	-40°C ≤ ϑ_S ≤ 90°C
Relative humidity H	5% ≤ H ≤ 95%
Operating voltage V_B	9.0V ≤ V_B ≤ 16.5V
Maximum voltage V_{Max}	18.5V (1 hour); 26.0V (1 min)
Power consumption P_{Max}	< 1W
Interface	LIN 2.0
Plug	AMP2-967642-1
Pin connector	Terminal 1: Clamp 15, Terminal 2: Clamp 31 Terminal 3: Output (LIN port)
Plug frequency	≥ 10 x
Mounting	Bayonet socket and dovetail guide
IP protection classes	IP64 + IP67
Identification marking	Interchangeable inserts or labeling with ink/laser
Dimensions	≤ 45mm x 35mm x 25mm
Weight	< 20g
Recycling	End of life vehicle (ELV) directive

The air quality sensor is used to activate the recirculation mode of the HVAC system. Additional vehicle-specific data such as outside temperature ϑ_A (from a outside temperature sensor NTC_1), vehicle speed v and closing frequency n of the recirculation flap are included. Fig. 2a shows the principle for controlling the adjustment of the angle α_U of a recirculation flap actuator M_1 in a vehicle HVAC system using an air quality sensor R_1. The signal process an electronic control unit (ECU).

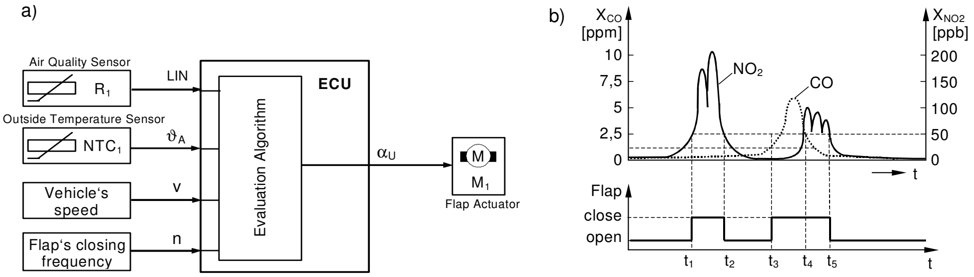

Fig. 2: (a) Principle for controlling the recirculation flap of a HVAC system using an air quality sensor; (b) Schematically characteristic of traffic specific concentration changes of CO and NO_2 and the corresponding concentration dependent switching behavior of the recirculation flap

Fig. 2b shows that overstepping a certain threshold concentration X_{CO} of CO and X_{NO2} of NO_2 leads to a corresponding closing response of the recirculation flap. During the time span $t_1 \leq t < t_2$ the closed flap state is caused by an increased NO_2 concentration. At $t = t_3$ an activation of the recirculation mode occurs by an increased CO concentration in ambient air. The CO concentration will go below the threshold at $t = t_4$, but at the same time there is an increased NO_2 concentration, which results in retaining the recirculation flap in the closed state. This state is lifted only at $t = t_5$ when the NO_2 concentration is below the threshold concentration. Sensible detection limits for the corresponding traffic-specific smell situations are, for example, 50ppb for NO_2 and 1 ppm for CO.

2. Automotive Suitability

For the complete mechanical and climatic qualification test, 20 samples are used for different tests, as related in Fig. 3. Simultaneously, other samples are tested for specific ingredients to demonstrate the chemical stability.

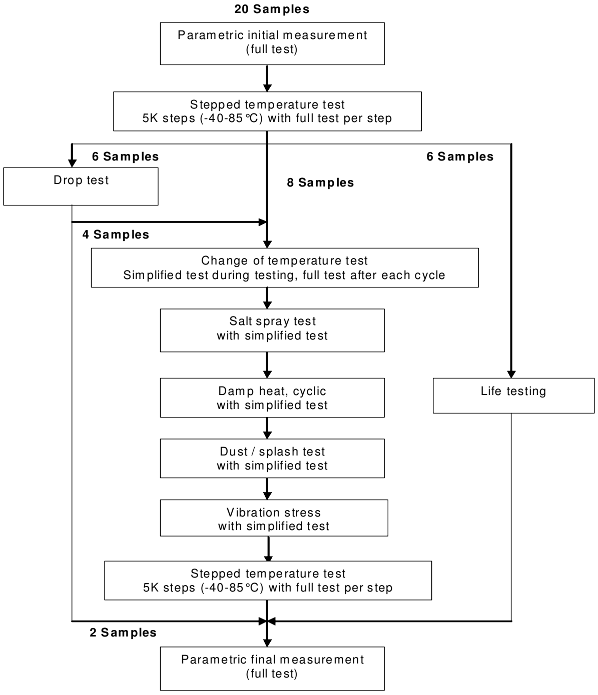

Fig. 3: Test procedure for mechanical and climatic classification [2]

Before and after the test procedure, a comprehensive full test of the samples is taken. During the procedure, simplified tests for functionality must be performed. The full test includes the testing of all electrical parameters and measured values at room temperature with a successively carried gas loading with NO_2 concentrations between 50ppb and 10ppm, with CO concentrations between 1ppm and 50ppm, and with a NO_2-CO gas mixture with a concentration of 500ppb NO_2 and 10ppm CO. The simplified function is a test at room temperature, electrical load and a gas loading with 500ppb NO_2.

The following shows in detail the tests that the sensors are submitted to: In a stepped temperature test, the sensors are conditioned in temperature steps of 5K in the range from -40°C to 85°C and subjected to a full function test. In the range from -10°C to 85°C, the samples are thereby exposed to the specified gas concentrations at the subsequent rise in temperature and rinsed with synthetic air.

The use of the sensor in the exterior of vehicles requires them to be leak-proof to dust and splashing water, and the resistance to salt fog. The dust and splash water test will be performed in accordance with the required IP class. For the salt spray test, samples are exposed to the spray in 6 cycles per 8 hours under electrical load. After a rest period of 8 hours, the samples are subjected to a simplified function test at $\vartheta = 50°C$.

In the change of temperature test, the samples continuously pass the operating temperature range from -40°C and +85°C while being permanently tested for functionality. The tests are performed with 30 cycles per 8 hours. After each cycle a full test is required. In a cyclic damp heat test, the samples are exposed to high humidity (H = 95% r.h.) with temperature changes between 55°C and 25°C. The components are bedewed here. The test is carried out under electrical stress. At the end, a simplified function test at a temperature of $\vartheta = 55°C$ is carried out.

In the drop test, a sample falls twice in each spatial axis on a concrete slab from the height of 1 meter. The sensors should then show no damage. The air quality sensor, as part of a growing body, has to be subjected to a vibration test and a mechanical shock test. The samples must be swung in their original holders in all axes for 8 hours with superimposed temperature profile of the temperature cycle test. The shocks are performed ten times for each spatial axis direction with a minimum speed of 500 m/s^2 over 12ms. In vibration and shock test, the samples are electrically loaded and their values are evaluated.

The life test, a lifetime of 15 years is simulated. For this purpose, we propose a strain on the air quality sensors of 12,000 operating hours with 54,000 on/off cycles with a superimposed temperature cycle test.

Through ingredient tests, the chemical resistance of the sensor is tested against the following test media: water, snow/ice, acid rain, road salt, transmission fluid, motor oil, refrigerants (R134a, R152a), hydrogen, battery acid (sulfuric acid), coolant, premium fuel, diesel fuel, biodiesel, natural gas, brake fluid, glass cleaner, alcohol, ethanol, methanol, hydraulic oil, kerosene, benzine, preservative agents, engine cleaner to engine wash, soap, axle fluid and starting means. The test samples are wetted at room temperature with the respective test medium and then aerated for one hour. Oils, detergents and preservative agents are ventilated at a temperature of $\vartheta = 70°C$. The test samples must be fully functional 2, 8 and 24 hours after the test.

In addition to the mechanical, climatic and chemical classification of the sensor, the electrical functional requirements and EMC robustness tests are met [2].

3. Conclusion

In this work the most important requirements for automotive sensors in the example of an air quality sensor were presented. In particular, the securing of the electrical sensor functions in superposition with strict environmental conditions was discussed.

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