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An Improved Test Set with Switchable Oscillator for Dual-delay Line SAW Gas Sensors

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Summary:
The paper presents a new switchable test set dedicated to dual delay line SAW gas sensors. The described network is a switchable oscillator operating at frequency of approx. 205 MHz adopting dual delay line fabricated by SAW Components. It was successfully applied to detect traces of DMMP (Dimethyl methylphosphonate) being the simulator of combat poisoning agents in the air. The oscillator discussed in the paper adopts a single active network, multi-state phase shifter and electronics switches to alternate excitation of two delay lines, so that it offers much better temperature properties in comparation to the existing solutions using two separate temperature sensitive oscillators. The measured frequency to temperature sensitivity of the discussed test set is 10 times lower than the one built of two separated oscillators. Moreover, the proposed circuit, thanks to its alternate operation, eliminates the interaction between two delay lines placed on the same substrate.

Keywords: Switchable Oscillator, SAW Oscillator, SAW (Surface Acoustic Wave), DMMP - Dimethyl Methylphosphonate, Delay Line, Digital Transducer, Poisoning Agents.

Background, Motivation an Objective

The measurements of SAW sensors could be performed by the factory-built meters or dedicated electronic circuits that detect changes in electrical parameters of sensors caused by the occurrence or change in concentration of the detected chemical agent. An effective and simple way to detect changes in the electrical parameters of an SAW sensor is to include it as an element of the oscillator circuit to make the oscillation frequency dependent on the electrical parameters of the SAW structure.Therefore, electronic systems cooperating with the SAW sensors are often oscillators whose frequency follows the changes in the velocity of the acoustic wave and stems from the interaction of the sensor layer or structure with gas or vapour molecules in the surrounding atmosphere [1]. In such solutions, problems related to the suppression of oscillations in the feedback loop of the oscillator by the sensor layer or structure are relevant [1]. However, the application of an oscillator allows to achieve of a high resolution. The frequency of oscillations of the sensor and the oscillator circuit are sensitive to the ambient temperature.This work describes the structure with additional phase shifter and basic features of a switchable oscillator with an operating frequency of approx. 205 MHz Fig. 1.

It is based on the SAW dual delay line module from SAW Components that has been successfully used to detect trace amounts of a DMMP simulant of combat poisoning agents (Dimethylmethylphosphonate) in the air.

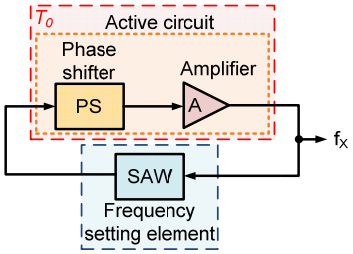

Fig. 1. Block diagram of SAW oscillator with additional phase shifter PS.

Description of the New Measuring Method

The response of the test set to the occurrence of the detected factor is observed as the frequency difference between the two oscillators. This method is effective when both sensors (both delay lines) have the same temperature, and the temperature sensitivity of both oscillators is the same. However, the assumption that the electrical parameters of the active networks of both oscillators are identical

and that thermal changes of their parameters that occur under operating conditions are identical might not be true [2].In an active network, the temperature influence on scattering parameters (both their modules and phase shifts) is observed [3]. These phenomena stem from the temperaturechanges of their operating points and transit frequencies [3]. In order to reduce the temperature influence on the active networks the authors have proposed a single active network that is switched between reference and sensorlines of the SAW as shown in Fig.2. Thanks to this solution, both SAW sensors share the same active network.

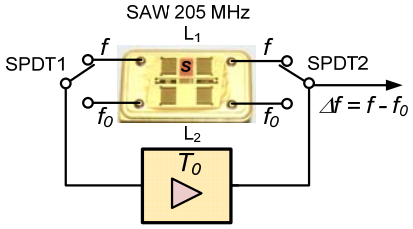

Fig. 2. Proposed test set consisting of a single active network and switchable SAW delay-lines.

In the proposed solution the signals are generated alternately.

Results

The operation of the proposed oscillator was examined experimentally. The influence of the temperature on the oscillator active network was evaluated using the automated test system. The effect of the device heating is shown in Fig.3.

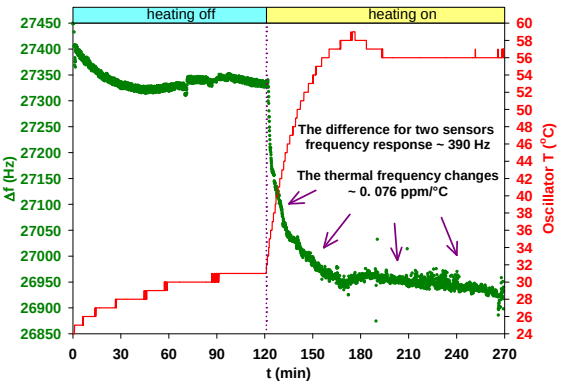

Fig. 3. Difference between sensors responses.

The absolute values of the frequency changes caused by the heating of the active network by the temperature 25 °C for both connected sensors about 4 kHz, which results in a thermal frequency increment of about 0.78 ppm/°C. The difference in the two sensors' frequency response is about 390 Hz, resulting in thermal frequency increment of about 0.076 ppm/°C. In order to verify the experimental results, the frequency change ratio (FCR) caused by the increment of the generator's active network temperature was found. In summary, the meanvalue of theoretical FCR determined based on the presented simplified model is about 6.4 which means that the mean computed frequency change caused by temperature increment of the active part of the switched oscillator is 6.4 times smaller than of the separated oscillators whereas at the measured value it is about 10.The calculated value is less than the measured by 36%. This effect can be explained by the non-linearity of the phase characteristics of SAW sensors shown in Fig.4.

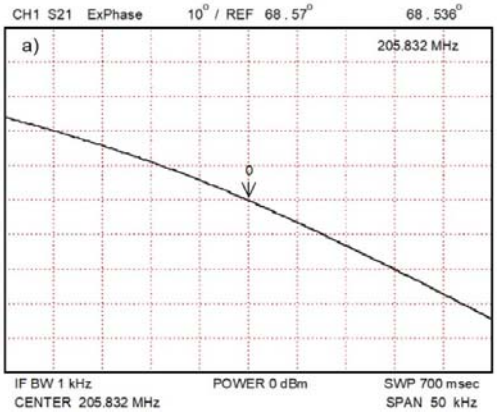

Fig. 4. Example of the S_{21} phase characteristic of the SAW1 sensor in the vicinity of the oscillation frequency.

Conclusions

The raport introduces a new switchable test set for SAW dual-delay line gas sensors with the multi-state phase shifter. There are presented theoretical background and experimental results of the developed switchable SAW oscillator operating at the frequency of 205 MHz.The presented oscillator adopts a single active network to alternate excitation of two delay linesmaking the SAW gas sensor. It offers significantly better temperature properties over existing solutions where two temperature sensitive oscillators are applied and its measured frequency to temperature sensitivity is 10 times smaller than those achieved in commonly used test-sets.

References

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