Gas Detection Using a Multi-sensor Device with Pump Control and VOC Sensor

Universal Pump Sensor Control

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***Abstract*— This paper deals with the development and investigation of a volatile organic compound (VOC) system for different scenarios. The integrated multi-sensor unit can detect different gases through the integrated 3-fold VOC sensor, whereby a continuous measurement takes place. The system-integrated flow control, with pump and flow sensor, allows the gas molecules to be transported directly to the VOC sensor. The entire measurement is permanently stored on an integrated Secure Digital (SD) card. If the previously determined limit range is exceeded, an alarm is generated. Due to the combination of different components, numerous applications are possible. The system is the first step or a tool towards further developments in the field of gas sensors and is primarily used for the validation of chemically based gas sensors, and it is still largely extended by application-specific influences.**

Keywords-gas detection; VOC; pump control; multi sensor device.

I. MOTIVATION

The environmental pollution caused by air pollution is becoming increasingly important nowadays. Cities and densely populated villages suffer from the enormous pollution, but also other critical points at which people gather. Pollution caused by VOC plays a significant role and is addressed by the VOC Solvents Emissions Directive [1][2]. In order to counteract the causes, sporadic measurements are carried out in order to detect the rate of pollution and to define the threshold values. Gas fluctuations and critical concentration peaks are often overlooked, which can lead to locally extreme environmental problems, although the specific causes can often not be determined immediately. A system which can be deployed in a mobile manner, and hence which can be deployed in a distributed manner, enables chances to monitor pollution in various significant scenarios, e.g., in the areas of agriculture, chemical industry, and traffic.

Innovation is the catalyst for the technology of the future. It is important to develop new and better technologies that can continuously monitor the environmental impact. In the recently at BAM developed Universal Pump Sensor Control (UPSC3) module, different components and sensors are fused. The combination of the individual components makes the UPSC3 module an excellent monitoring and reference system. Measurements over long periods are possible, for mixed gas loads or for certain gas measurements. This paper describes the UPSC3 sensor module, which can be used for different application scenarios due to its functionalities [3]. The system is part of a mobile sensor network of several sensor units, which can also be used as standalone system.

Section 3 describes the structure of the system and how it works, followed by initial tests and comparison with commercial sensors in section 4. The paper is rounded off with the application examples of the system and their advantages in section 5 and 6. Section 7 shows the work to be done to optimize the tool and the measurement process.

II. SYSTEM DESCRIPTION

The system and the sensors are protected from mechanical effects by an aluminum housing, see Figure 1. An air duct is provided for sucking and discharging the gas mixture. The exhaust air channel directs the induced gas-air mixture back into the environment from the commercially available VOC sensor, the sensor used is based on metal oxide semiconductor sensor technology. In order to be able to use the system on a mobile basis, all interfaces, such as supply voltage, communication and memory card slot are routed sideways. Any battery with 12 V DC voltage can be connected to the system as a power supply. The manual adjustment of the values and the monitoring of the measurement is possible on the 2.8 "touch color display; the 3 x 4 keyboard also serves as a manual entry of the values (sensor selection, threshold value, temperature, etc.). Further connection possibilities are control signals for the opening and closing of the disk valve, by servo motor to regulate the gas supply at the calibration stations, as well as I/O pins for the control of external hardware (e.g., interrupt).

Figure 1. UPSC3 front view with screen and key pad.

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The connections for the signals as well as power supply are on the side.

A. UPSC3 Schematics

The system is divided into 7 blocks and figure 2 shows the sections. The control of the individual components and the sensor evaluation is handled by a 16 MHz AVR 8-bit microcontroller. In doing so, the system has been kept universal, and several interfaces allow communication with different devices. From the RS232 interface with 8 V Transistor-Transistor logic (TTL) level to Universal Asynchronous Receiver Transmitter (UART) interface with 5 V TTL level to keep the possibility of the connection to the older devices. The I2C bus allows the system to communicate with other sensors or systems. Table 1 shows the functionality of the components in function groups.

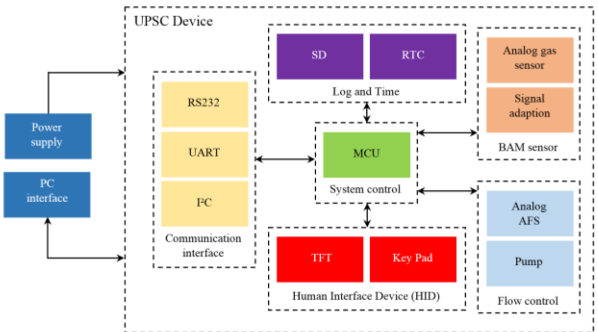

Figure 2. Schematics representation of the functional areas of the system.

TABLE I. COMPONENTS AND FUNCTIONS

Component	Group	Function
RS232	Communica-tions Interface	Communication with PC (COM Port)
UART		Communication with PC (USB Port)
I2C		Communication with main device (Slave)
TFT	HID	Control the Device with touch screen Show the module and sensor data on TFT
KeyPad		Enter values
RTC	Log and Time	Current time
SD card		Save all measurement data into file Can be used for configuration file
AFS	Flow control	Current airflow
Pump		Control airflow
Gas sensor	BAM Sensor	Detects gas changes in the air
Signal adjustment		Control heater and signal adjustment
MCU	System control	Control components and calculate results

Table 1 describes the currently used modules of the system. Further components are planned, more in Section 7.

B. Modular design

Figure 3 shows the modular design of the system. This principle offers the user, as well as the developer a fast troubleshooting and the possibility of system expansion.

Figure 3. Modular design of the system

The UPSC3 system has been designed according to a modular principle. Components which do not represent a large disturbance for the measurement can be exchanged. This has the advantage that the user is also able to carry out repairs autonomously or to replace components. The modular components are:

- MCU (Micro Control Unit)
- Voltage regulators
- RTC
- All peripherals

C. Gas detection principle

Figure 4 shows the principle of the gas detection, whereby the air channels, the air flow sensor, and the pump play a decisive role in the gas detection.

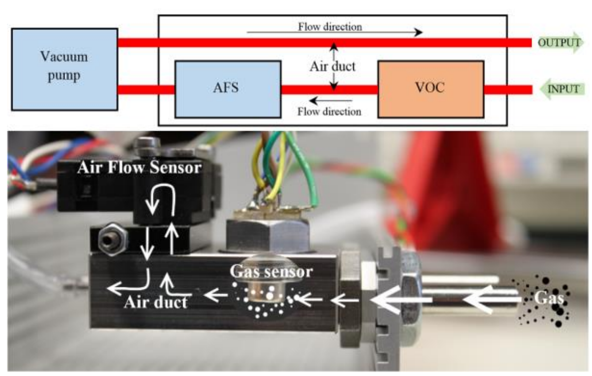

Figure 4. Gas sensor module with air flow sensor and air ducts

The transport of the gas mixture is carried out by the pump at a rate of 50 ml/min to 200 ml/min. The speed can be adjusted manually and is automatically adjusted by occurring loads or constriction of the air channels. The air flow meter quickly detects these fluctuations and initiates corresponding measures by means of the system. The gas mixture is then passed through the air channel system in which the VOC sensor is located, then the sucked air gas mixture is led back into the free environment.

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The sensor layers located in the VOC sensor change their resistance as soon as the gas molecules settle on the layer surface or with the increasing concentration. The concentration cannot be determined unequivocally, but can estimate the danger level by increasing the initial value. In order to operate the VOC sensor and reactivate it more quickly during the measurement, the implemented heating element (Pt10), which is located in the immediate vicinity of the layers, is kept constant at a temperature. If temperature fluctuations occur, the system automatically adjusts the temperature. This has the advantage that the temperature changes in the surroundings can also be detected and compensated.

D. UPSC3 Flow chart sequence

Figure 5 shows the program sequence of the entire system. At the start of measurement, the sensors are read out in predefined sampling times and the current values are displayed on the TFT and stored on the SD card.

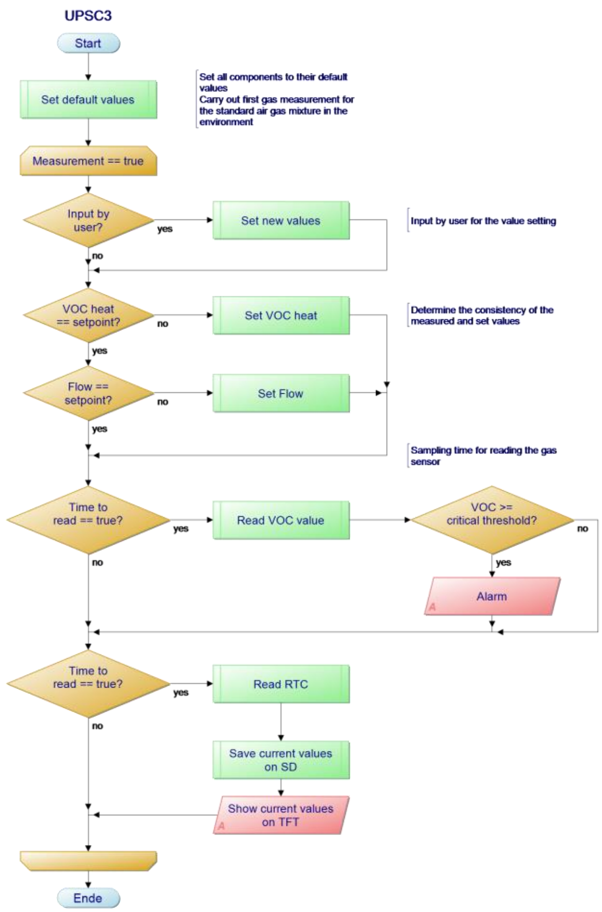

Figure 5. Main functions and the sequence of UPSC3

After the system is switched on, all components are initialized and the initial values are set. The measuring cycle is then started. The air flow and the VOC heater are set to the minimum values which are necessary to operate the system. During the measurement, interrupt-controlled inputs are monitored by the system. If an input is made, the measurement is stopped to perform the input. As soon as the input is finished, the set values are checked and compared with the current values. If the values deviate from one another, then a subsequent correction or adjustment of the values takes place.

Due to the relatively sluggish gas sensor, the values in the secondary clock are read out, displayed on the display and stored on the SD card. All sensor values are formed as a mean value from a 32-value ring memory. If the gas concentration exceeds the threshold values, these can be changed during operation, an alarm occurs in the form of a display or the threshold value can be exceeded by activating external hardware. All values are still stored on the SD card.

III. LABORATORY TESTS

Figure 6 shows a series of measurements in a closed room. The measurement took several hours to investigate the stability of the sensors and the system. The built-in UPSC3 VOC sensor and own signal processing (S1, S2, S3) is shown on the primary y axis, without the calculation of the resistance layers, only the analog voltage values however, the influence of gases can be explained, and the reference VOC sensor and signal processing (R1, R2, R3) is shown on the secondary y axis [4]. With the integrated pump and the flow sensor, conclusions can be drawn about the concentration of the gas. The reference is an identical VOC sensor, which is controlled by an evaluation tool kit developed by the manufacturer via USB [5]. Figure 6 shows not a direct comparison of the UPSC3 with the reference VOC sensor, this attempt should validate the control of the VOC sensor by the UPSC3 system and allows for classification of the sensor signals in regard to gas identification and quantification.

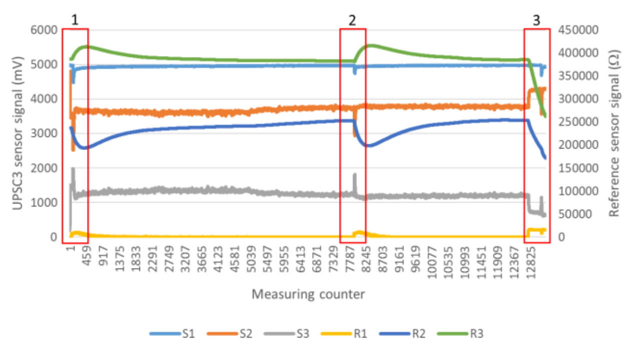

Figure 6. First measurements with UPSC3 and reference VOC

The experiment was carried out in three steps: Step 1 shows the initialization and the settling of the sensor layers after commissioning of the sensors. The heating element (Pt10) was brought to an operating temperature of 350 °C. Step 2 shows the detection of a gas, which is a 100 % essential oil called "exotic". The oil was held directly (1 cm) against the sensors, resulting in the deflections shown in Figure 6. In the last step, which is number 3, the operating

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temperature of the heating element was increased to 400 °C, which resulted in a change in the overall course of all layers. The influence of the temperature change in the direct connection of the Pt10 with the sensor layers.

IV. Applications

UPSC3 is primarily used to calibrate and validate new gas sensors, but its application is very wide. Figure 7 shows a large part of the application scenarios, ranging from indoor applications (laboratories), wide open areas (farms) and agglomerations (cities), as well as critical locations where a high concentration of gas poses a threat to humans (gas stations).

Figure 7. Application scenarios for the UPSC3 system

The module is primarily designed for the calibration of newly developed gas sensors. Other application scenarios are shown in Figure 7 but are not included in this paper.

V. Features and benefits

- User-friendly
- Sampling and threshold monitoring
- Pattern recognition
- Standalone System (mobile)
- Robust aluminum housing
- Modular design
- Defective components are quickly interchangeable due to the modular design
- BAM multi sensor system device enables TCP/IP communication, too

VI. Conclusion

By the interaction of the pump with the air flow sensor and the VOC sensor, it is possible to develop a process which can determine the concentration of gases. By regulating the temperature, the temperature fluctuations of the environment can be compensated. Due to the small size and the possibility of the battery connection to the system, the mobility is given, the UPSC3 system could be carried along.

The detection of the gas takes place by the 3-fold VOC sensor, which can detect gases through its different layers. The pump supports and transports the air-gas mixture into the air ducts of the system. The detected values are displayed cyclically on the display and stored simultaneously on the SD card. If it is not possible to set the values directly on the system, configurations are also possible with a computer via the UART, RS232 or I2C.

The primary use of the system is to classify gas sensors under laboratory conditions that require control of external modules. The use in large areas is complicated by the lack of radio communication of the system.

VII. Outlook

In order to improve the system and make the measurements even more efficient, further sensors are planned for implementation. The sensors are placed directly in the air duct, the sensors will record the air humidity, as well as the temperature, so other parameters can be determined which are taken into account during the classification of the measurement. The validation of the system takes place primarily in a hermetically sealed desiccator, with selected gases being used to define the accuracy of the measuring system. Through this validation setup, a pattern recognition for different gases e.g., Benzene, will be developed. Remote control of the system via a web interface is also planned and partially implemented. The control system adopts a powerful mobile BAM control unit, which is also under development. For mobile use, an optimization of the power requirement is still planned.

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