CHEMICAL ENGINEERING TRANSACTIONS

VOL. 68, 2018

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Selena Sironi, Laura Capelli

ISBN 978-88-95608-65-5; **ISSN** 2283-9216

DOI: 10.3303/CET1868035

Automatic Odour Detection System Design of Indoor VOCs Based on MCU

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In order to monitor indoor odour and improve the quality of life, this paper designs one MCU-based automatic odour detection system for indoor VOCs by taking the STM8S903K3 MCU as control element. The sensors were used to collect the concentrations of inhalable particulate matter (PM) and odour gas indoors. When the concentration of volatile organic chemical (VOCs) exceeds the set value, the system can automatically determine and emit an audible and visual alarm. This design has the characteristics of low power consumption, easy portability, and high sensitivity, etc. It is a convenient and practical odour detecting tool by detecting air odour in complex environments.

1. Introduction

The indoor VOCs odour mainly comes from the indoor irritating gases that cause harm to the human body, such as formaldehyde etc. House purchasing and decoration is a process that ordinary people must experience in their lifetime. Some pollution incidents in the decoration spread on the Internet, which has made people to know about some professional words such as excessive formaldehyde and TVOC pollution etc. Some manufacturers use unqualified raw materials to make profits, causing certain wood, glue and other materials that don’t meet the national standard to flow into the market. In the future use of these materials, the slowly released toxic gases will greatly endanger human health (Zhao et al., 2016; Parker et al., 2012; Torretta et al., 2013). For this, the government has strengthened the market supervision, so as to ensure the non-standard products away from the market and increase the illegal cost of the illegal enterprise. Moreover, more and more people choose to test the pollution indicators indoors before moving into the newly renovated house and thus avoid unintended consequences. According to the survey, people spend more than 80% of the time in the house, so the air quality inside the house is vital to human health. Relevant epidemiological studies have confirmed that the incidence and mortality of lung problems in the population are closely related to atmospheric PM concentrations, especially that inside the house. The indoor odour has a great influence on people’s quality of life, and high requirements has been thus proposed for its detection technology (Jeong-Hyeon et al., 2014; Hu, 2018). In particular, along with the improvement of living standards nowadays, the people have put forward new requirements for the air quality in public places. Therefore, this paper designs an automatic detection system for indoor VOCs odour based on MCU, which is convenient for users to detect indoor odour concentration in time.

2. Application of sensor technology in odour detection

In recent years, with the rapid expansion of the power electronics industry, the semiconductor industry, and the computer industry, the equipment technology level of various controller chips has been getting higher and the computing speed been getting faster. Various control chips and semiconductor devices in line with Moore’s Law has also become more integrated and modularized. In such context, the detection accuracy and technical level of the air odour detecting device are also getting higher and higher, with more integrated functions (Jia, 2018). The air odour monitoring equipment is oriented towards real-time, high-precision, low-power consumption (Osada et al., 2013). Due to the endless stream of various types of equipment, the quality and function of equipment have been gradually improved under the market economy.

Please cite this article as: Li F., 2018, Automatic odour detection system design of indoor vocs based on mcu, Chemical Engineering Transactions, 68, 205-210 DOI: 10.3303/CET1868035

In the past half century, sensor technology has developed rapidly, and various test equipment has undergone many changes in the process of laboratory sampling, analysis programs, ad real-time detection on site. Due to the rapid development of digital chips, many enterprises such as Qualcomm and Samsung have been able to portray semiconductors in the width *14nm*. This technology has made a leap in sensor technology. More accurate and compact sensors have entered the market, and gas detection devices have become more portable. The advantages of electrochemical sensors with digital analog chips in the detection device are more obvious (Banerjee et al., 2016). At present, the Ministry of Industry in Japan officially recommends the use of the electrochemical sensor-based formaldehyde analyser to detect indoor gas quality.
At present, the market is mainly dominated by the 7575 indoor air VOCs odour tester produced by American TSI and the Quest EVM-3 air odour tester produced by American company 3M. The TSI 7575 has a multi-function probe for plugging and unplugging to detect humidity, CO gas concentration, CO_2 gas concentration, temperature, wind speed, VOC and other parameters, while the Quest EVM-3 air quality detector can measure the inhalable PM, gases, toxic gases, and the VOC concentration (such as formaldehyde) as well as the relative humidity, temperature and wind speed indoors (Gao and Acar, 2016; Guo et al., 2012). In the past two years, related companies in Germany have also developed various types of test equipment. Now many domestic companies in China have produced indoor gas detection equipment in houses, but there still exists certain gap from the foreign products in terms of equipment quality.
Due to the people's increasing demand for health, domestic researchers have carried out many related researches on the monitoring of indoor VOCs odour gas quality, e.g., the *STC12* was used as the control core of the odour detector, to monitor various harmful gases in the house at the same time, which fills the gap of various gases detection in China (Zhang et al., 2013). The advantages of this detection system are: the sensitive system and more accurate measurement of harmful gas concentration; however, the host computer for related data processing isn't designed in this system, and remote monitoring cannot be performed, which indicates the limited application of the device in some degree. In addition, some scholars have studied the wireless data transmission technology in multi-gas sensors. The research shows that the six gases in houses are controlled by the MCU simultaneously by six sensors. Meanwhile, the communication chip is used to send the data to the host computer for analysis and processing of related data, and the alarm function is achieved. But, the device cannot monitor the gas at any time and any place, thereby increasing the limitation of the device.

3. Overall design concept of system

The MCU-based indoor VOCs automatic odour detection system mainly consists of two parts: hardware circuit and software design. The hardware circuit of the system mainly collects the concentration of inhalable PM and irritating gas in the air indoor by two sensors: the *GP2Y 1010AL* inhalable PM sensor and the *TGS 2600* irritating gas sensor. The sensor can generate an analog signal of the corresponding concentration value and then output it to the *STM8S903K3* Single chip microcomputer. This signal is received by the I/O interface of the MCU and then processed accordingly. Besides, the liquid crystal display (LCD) is used as an interface for human-machine dialogue to display the concentration of inhalable PM and irritating gases; when the concentration of these two exceeds the system threshold set, one I/O interface should be designed to connect buzzer and issue the alarm; the keying circuit is connected through the I/O port for adjusting the system parameters. For the software, the modular programming method is adopted. Each subroutine is relatively independently packaged, thus making its function independent and easy to expand. The hardware circuit of the system mainly includes the main chip and its peripheral power supply circuit, the inhalable PM sensor circuit, irritating gas sensor circuit, LCD circuit, and buzzer alarm circuit. Figure 1 shows its structure.

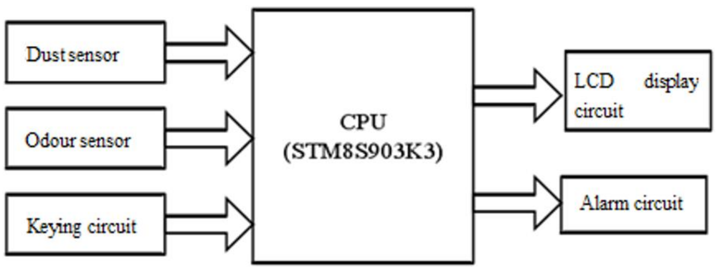

Figure 1: System hardware block diagram

4. System hardware design

4.1 Main chip and peripheral circuits

STM8S903K3 is a high-performance 8-bit MCU based on the *STM8* kernel by STMicroelectronics company. *STM8S903K3* is the RIA version of the *STM8S* series. Compared with the *ST7* series, the 8-bit kernel of *STM8S* has been improved, its performance ratio has been increased by nearly 10 times, and the code has been saved as much as 30%. In terms of performance, *STM8S* adopts the advanced Harvard architecture, and with 16-bit index buffer and stack pointer, as well as 16Mbyte linear address storage space, advanced addressing modes and other advanced features, it can effectively support users to program in C language. The core processing speed of CPU can reach an average of 1.6 clock cycle for each instruction, and the maximum performance under the 24MHz crystal oscillator is 20MIPS. Both the digital port and the analog port are designed with active anti-interference to withstand the interference currents below 4mA.

The *STM8S* series also provides users with two programming modes: application programming and online programming. The single-line hardware interface is provided in both programming modes, with the characteristics of ultra-high-speed programming relative to the memory. In the applications such as home appliances, battery-powered devices, power tools, HVAC equipment, and motor controllers, the *STM8S* series has four built-in energy-saving modes that allow developers to design appropriate power management strategies and reduce device power consumption according to demands. The free development environment and friendly development software make the MCUs of *STM8S* series to be widely used worldwide. The *STM8S* series has multiple packaging types such as 32 pinout-80 pinout LQFP, 20 pinout-48 pinout QFN, and 20 pinout TSSO, making it suitable for different applications.

Alarm circuit: When the inhalable PM and irritating gas exceed the standard, the alarm reminds the user to take relevant measures.

Keying circuit: Press the S1 button for 5 seconds to turn on the device; press the S2 button to turn on the device; tap theS1 button to set the device function; both buttons of S1 and S2 can set the inhalable PM and odour alarm threshold. Figure 2 shows the related circuit diagram.

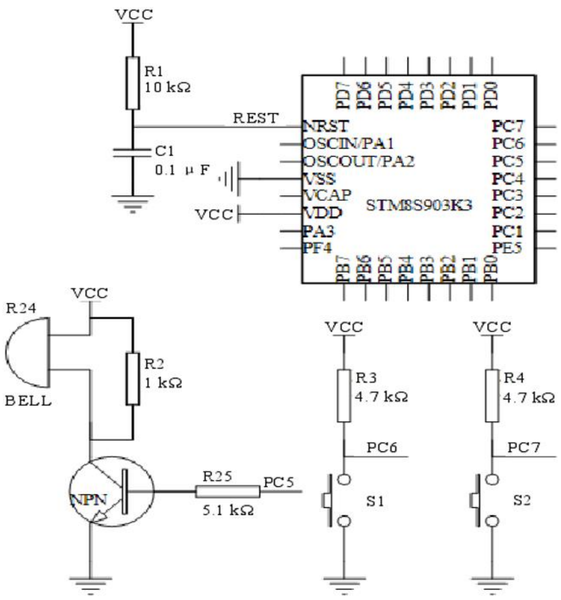

Figure 2: Main chip and peripheral circuit

4.2 Sensor circuit of inhalable particulate

For the indoor inhalable PM detection systems, it’s required that the inhalable PM sensors are easy to maintain, long lasting, stable, and highly accurate. According to the characteristics of inhalable PM in the house, the *GP2Y 1010AL* inhalable PM sensor was selected. This sensor can measure the small particles above 0.81μm, as one more cost-effective sensor of all related products.

According to the working principle of the *GP2Y 1010AL* sensor, the design of its hardware circuit module is shown in Fig.3. Using the LED to drive the PD4 pinout, *GP2Y 1010AL* receives the detection command control signal of inhalable PM and begins to detect the particulate matter; the detected signal is fed back to the PD3 pinout of CPU in the form of duty cycle. The input signal is converted to the concentration of inhalable PM according to the duty cycle of the input signal, and then displaced on LCD.

In order to improve the detection accuracy of inhalable PM, when designing the board, the high-frequency filter capacitors C1 and R3should be placed as close as possible near the CPU pinouts to prevent electromagnetic interference. The electrolytic capacitor C2 should be placed as close as possible to the VLED pinout of the inhalable PM sensor and also be reliably grounded to prevent the LED power supply to the inhalable PM sensor from becoming unstable due to interference.

4.3 Sensor circuit of odour gas

Since the common odour gas in households in China is produced by cigarettes and cooking fumes. The *TGS2600* irritating gas sensor is selected in the system. It is the commonly used sensor for purifier products or air detectors in houses with the advantages of high sensitivity to cigarettes and cooking odour, long service life, low cost, and the like. The circuit module is shown in Figure 3.

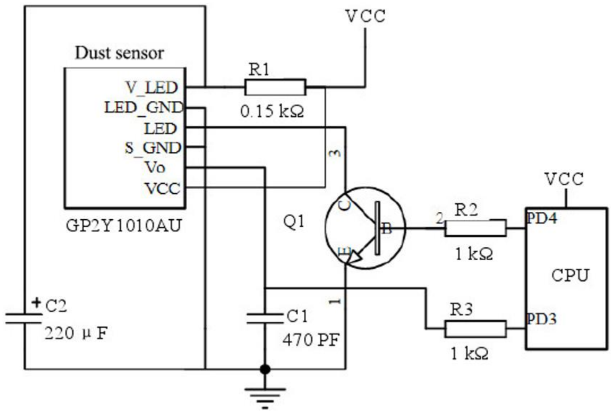

Figure 3: Application circuit of odour gas sensor

The normal operation of the sensor requires the application of two voltages: the voltage of heater (VH) and the voltage of circuit (VC). VH is applied to the integrated heater for maintaining the sensitive device at a specific temperature suitable for gas detecting. VC is used to measure the voltage across the load resistance (R1) in series with the sensor. The detected odour electrical signal is transmitted to CPU, which converts it to an irritating gas concentration, and display it on LCD.

In order to improve the detection accuracy, the high-frequency filter capacitor should be placed as close as possible to the PB2 pinout of CPU to avoid inaccurate signal sampling caused by the loaded interfering signals on the long-distance PCB printed circuit board. Since the gas sensor itself is a heating element, it should remain at a sufficient distance from the temperature sensitive element in the PCB design.

4.4 Drive circuit for LCD display

HT1621D is a memory mapping and multifunctional LCD drive. Thanks to its software configuration, it's applicable to a variety of applications, including LCD modules and display subsystems. Figure 4 shows its circuit module.

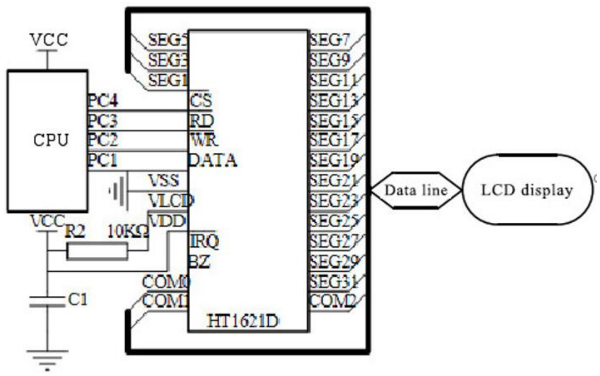

Figure 4: LCD drive circuit

5. System software design

The system is programmed with C language, and easy to expand. The program consists of several modules: data acquisition and processing, display, key scan and alarm.

5.1 Main program flow chart

After the system is started, the program needs to be initialized. Then, the main program loops through the module programs such as data acquisition, display, key scan, and alarm to complete the air quality test. During the work process, CPU monitors the action of the button, and process the data of the inhalable PM and the odour gas sensor in real time so as to determine whether the concentration of these two exceeds the standard. If their concentration exceeds the set standard, LCD is used to give an alarm and display the concentration, and then it goes to the next cycle; if the concentration does not exceed the standard, LCD directly displays the inhalable PM and harmful gas concentrations, and then to the next cycle. The main program flow chart is shown in Figure 5.

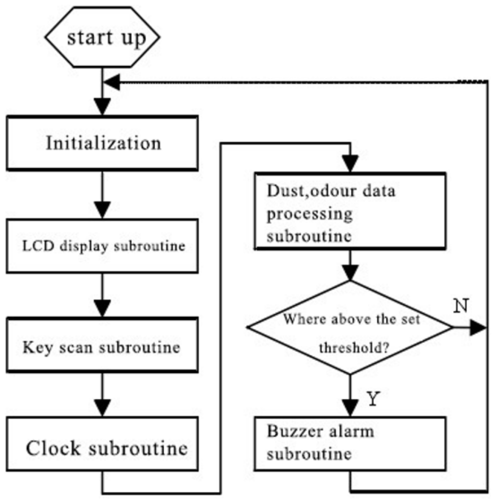

Figure 5: Main program flow chart

5.2 Air VOCs odour monitoring flow chart

In the operational state, the inhalable PM and the VOCs odour gas sensor are sampled in real time to produce the specific signal output to CPU, and these signals are converted to relevant inhalable PM and odour gas concentrations using the A/D internal device of CPU. To reduce the error, the cumulative means SS is used for program calculations. Then, it's determined whether the corresponding concentration is above the set threshold: if it is above the set threshold, the buzzer will alarm and display the inhalable PM and odour gas concentration; if below the set threshold, only the inhalable PM and the irritant gas concentration will be displayed, and the alarm will be cancelled. The main process is shown in Figure 6.

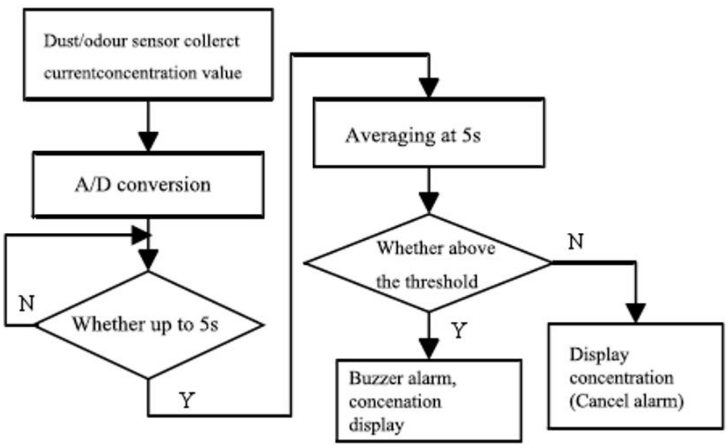

Figure 6: VOCs odour detection flow chart

6. Experimental results

In the experiment, the laboratory equipment, *TSI8533* inhalable PM tester and the *XP-329 IIR* harmful gas tester were compared with our system designed in this paper. The three devices simultaneously sampled the smoke and odour generated by the cigarette. The experimental comparison data is shown in Table 1.

Table 1: Experimental data comparison

Sampling point	Dust(*ug/m*^{3}) Lab equipment	Dust(*ug/m*^{3}) Our system	Odour(*mg/m*^{3}) Lab equipment	Odour(*mg/m*^{3}) Our system
1	499	505	2.11	2.08
2	420	410	1.60	1.63
3	350	345	0.80	0.82
4	150	140	0.15	0.16
5	50	55	0.05	0.07

Table 1 shows that the resolution of our system for the PM2.5 particles is lug/m^3, and that of the irritant gas concentration is 0.01mg/m^3, indicating that the detection accuracy of our system is still very high.

7. Conclusions

The system designed in this paper can monitor the concentration of inhalable PM and odour gas indoors in real time, and realize the functions of VOCs odour gas data collecting, analysing, storing, displaying and alarming. The MCU and its peripheral circuits can be used to better achieve human-computer interaction; the software design of the system is not complicated, with strong scalability, e.g., it can add sensors of temperature, humidity and carbon dioxide etc. to achieve more comprehensive air quality detection; combined with the air purification system, it can even become an intelligent environmental automatic purification device. As a whole, the design features low power consumption, portability, and high sensitivity. It is a convenient and practical odour gas detection tool for real-time monitoring of air quality in many complex environments.

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