CHEMICAL ENGINEERING TRANSACTIONS
VOL. 59, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Zhuo Yang, Junjie Ba, Jing Pan

ISBN 978-88-95608- 49-5; **ISSN** 2283-9216
DOI: 10.3303/CET1759022

Application of an Automatic System in Detecting Indoor Formaldehyde Content

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With the continuous improvement of people's living standards, more and more people pay attention to their quality of life and health, and the awareness of indoor air quality has been greatly enhanced. Formaldehyde is one of the most important substances in many indoor air pollutants. It mainly comes from plywood and pigments which is used in interior decoration. Therefore, the detection of formaldehyde gas is particularly important. To realize the monitoring of indoor formaldehyde gas concentration, an automatic formaldehyde monitor is designed in this paper. The article uses STM32F107 single chip microcomputer to control system. First, a Dart sensor is used to collect formaldehyde signals. Then, the signal is amplified and processed by the LTC1049 data processing module circuit. On the one hand, the real-time value of formaldehyde concentration can be displayed by LCD12864. On the other hand, when the formaldehyde concentration exceeds the preset threshold, the buzzer will sound the alarm. Finally, the system realizes the real-time monitoring of indoor formaldehyde concentration. In order to improve the measurement accuracy, the method of piecewise linear interpolation is used to correct the data. The experiment shows that the system has the advantages of good real-time, convenient operation, stable performance and intelligent. The system can be widely used in the monitoring of formaldehyde content in indoor air.

1. Introduction

At present, people pay more and more attention to their quality of life and health, and the awareness of indoor air quality has been greatly enhanced. Indoor air pollution seriously endangers people's health, and the detection of air quality has become one of the main methods to judge air quality standards. Formaldehyde, as one of the main sources of indoor air pollution, has attracted more and more attention. Therefore, the detection of formaldehyde gas is particularly important. In this paper, the STM32F107 microcontroller is used to process the formaldehyde signal collected by micro current amplifier. In order to improve the measurement accuracy, the method of piecewise linear interpolation is used to correct the data. The experiment shows that the system has the advantages of good real-time, convenient operation, stable performance and intelligent.
Formaldehyde is one of the most important substances in many indoor air pollutants. It mainly comes from plywood and pigments used in interior decoration. China's national standard provides that the maximum allowable concentration of formaldehyde in indoor air is 0.08mg/m3, and the highest allowable concentration of formaldehyde in public places is 0.10mg/m3 (Chen and Huang, 2007). When formaldehyde concentration is 0.10mg/m3, it has peculiar smell and discomfort, and when it exceeds this concentration, it can cause nausea, cough or even emphysema. However, when the concentration is 30mg/m3, it can cause death (Cheng and Huang, 2007). Formaldehyde is a kind of colourless gas which can stimulate the smell. It is also a potential carcinogen, which has a great harm to human health. Many diseases are related to formaldehyde, such as asthma. Both WHO and the United States Environmental Protection Agency list formaldehyde as a dangerous carcinogen and an important environmental pollutant (Li, 2007; Wang and Zhang, 2009). In China's priority list of toxic chemicals, formaldehyde ranks second (Du Juan (2010)). Formaldehyde can stimulate the respiratory tract and skin of the human body, disturb the nervous system, reduce immunity, and have the effect of carcinogenesis. In 2006, the international agency for research on cancer classifies formaldehyde as a carcinogen. This shows that the toxicity of formaldehyde is very harmful to humans (Yasuko and Jiro, 2011).

Please cite this article as: Yanlin Tao, 2017, Application of an automatic system in detecting indoor formaldehyde content, Chemical Engineering Transactions, 59, 127-132 DOI:10.3303/CET1759022

There are 3 common methods for the determination of formaldehyde which are chromatography, spectrophotometry and potentiostatic electrolysis. Chromatography is a direct high-performance liquid chromatography (HPLC). Since this method relies on the chromatograph which is very expensive and complicated to operate, it is not widely used (Lan and Lu, 2013; Lv, 2011)). Spectrophotometric method is based on the reaction of formaldehyde chemicals to produce chromogenic substances, and then use spectrophotometer to determine formaldehyde concentration. The disadvantage of this method is that the detection accuracy is not high, the reaction time is usually longer and the operation is inconvenient (Liu et al., 2011; Hu et al., 2009; Huang and Zhang, 2009). In addition, the principle of constant potential electrolysis is to measure the formaldehyde concentration by measuring the diffusion current produced by the reaction of formaldehyde and electrode, but this method is of great error (Chen and Huang, 2007).
According to reports, the concentration of formaldehyde in indoor air measuring instrument, there are mainly 5 kinds of international which are the biosensor, electrochemical analyser, infrared differential frequency meter, spectrophotometer, colorimeter and so on (Manoonkitiwongsa et al., 2002). At present, laboratory chemical analysis is the main method to detect formaldehyde in indoor air. This method requires testing personnel to collect gas at the site and then brings it back to the laboratory for analysis. The method has high detection accuracy and accurate detection results, but the detection procedure is complex, the cycle is long and the cost is high. Therefore, the design of low cost, fast, easy to detect and simple operation of indoor air testing equipment is the urgent need in the domestic market. With the development of modern science and technology, especially the rapid development of electronic communication technology, the accuracy of measuring instruments is getting higher and higher, which makes the indoor measuring instruments and instruments develop rapidly in the direction of intelligence. SCM has many advantages, such as versatility, small size, low price, stability and reliability. It has been widely used in intelligent products, measurement and control systems and other fields (Chen and Huang, 2007).

2. Method for detecting formaldehyde

The formaldehyde sensor in this paper is an electrochemical formaldehyde gas sensor produced by Dart Sensor Company. It is a sensor that can really be continuously monitored without the need for any gas sampling or pump extraction, as shown in Figure 1.

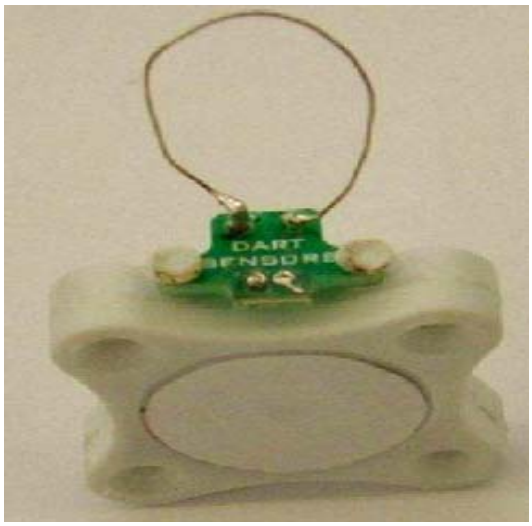

Figure 1: Physical diagram of Dart sensor

The sensor is based on the successful use of a breath type alcohol sensor and is suitable for monitoring in most environments (-20~+50 degrees Celsius). With this sensor, there are 5 major design features:
(1) Low cost. Simple structural design reduces costs and leads to more competitive prices.
(2) Long life. It uses components of a breath alcohol sensor that has been used in the world for more than 30 years. The accuracy, stability and permanence of the breath alcohol sensor have been verified.
(3) Fast response. A short and low impedance diffusion path makes it less responsive.
(4) Low power requirement. The fuel cell principle means that it does not require additional power supply. It requires electrical energy only during signal processing and display, so a simple small battery cell can be used.
(5) Good stability. The sensor allows for very long calibration cycles during use.

3. Hardware design of the system

3.1 Overall architecture design of hardware system

The overall structure of the hardware design of the indoor formaldehyde content detection system is shown in Figure 2. According to the actual functional requirements, the system is mainly composed of 5 parts which are the MCU core processor, electrochemical formaldehyde gas sensor, data processing module, display module and alarm module and other components. Because the system is in high performance, low cost, low power consumption and meets the requirements of various data transmission methods, the core control component of this system is STM32F107 based on ARM Cortex M3. The chip has the advantages of high performance, low cost, low power consumption, and rich on-chip resources.

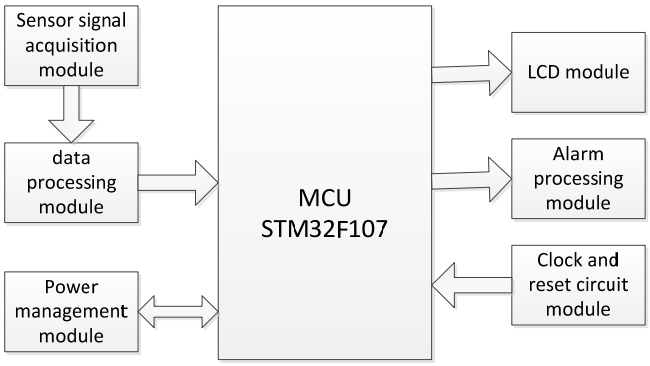

Figure 2: The overall structure of the hardware

3.2 Data processing module circuit

The weak current signal of the formaldehyde sensor is amplified by LTC1049. LTC1049 is a chopper stabilized zero amplification circuit, which can play good noise suppression and increase input impedance, and it is widely used in current mode amplifier circuit. The LM285 is used to provide a common mode signal, and it can suppress the ripple interference of the power supply. Finally, the output signal is amplified to be a stable voltage signal, which is collected by A/D of MCU. The data processing module circuit is shown in Figure 3.

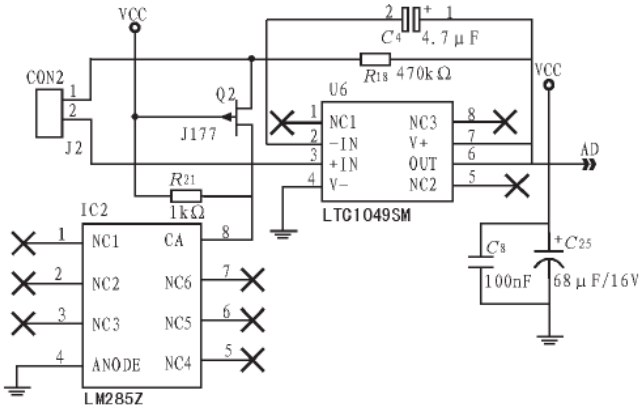

Figure 3: The data processing module circuit

3.3 Liquid crystal display module circuit

The system uses LCD12864 as monitor. LCD12864 is a graphics dot matrix liquid crystal display. It consists of row drives, column drivers, and 128 * 64 dot matrix liquid crystal displays. It can display graphics or display 8 x 4 Chinese characters. There are two kinds of interface methods between LCD12864 LCD module and MCU, which are direct access mode and indirect control mode. The system adopts indirect control method. This method does not use the data system of single chip microcomputer, but uses its I/O port to realize the connection with the display module. The liquid crystal display module and the data line connect to the MCU P0

port as the data bus, the other 3 root timing control signal line usually use unused SCM P2 port in I/O port to control. This access mode does not occupy memory space, its interface circuit has nothing to do with timing, and its timing is completely realized by software programming. Figure 4 is the connection diagram of LCD12864 and single chip.

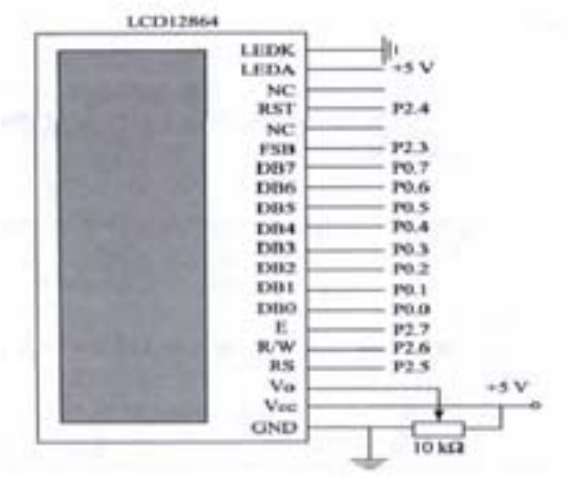

Figure 4: The connection diagram of LCD12864 and single chip.

3.4 alarm processing circuit

When the formaldehyde concentration exceeds the threshold, the smart node circuitry generates alarms. The alarm circuit is shown in Figure 5. In this circuit, the triode is used as on-off device. When the buzzer is alarm, the output is low, and the transistor is connected. The alarm processing circuit can also connect the I/O of the STM32F107 microcontroller to other linkage devices, such as relays. When the alarm is started, the linkage equipment is opened, and the on-site treatment is carried out to reduce the harm of formaldehyde to people.

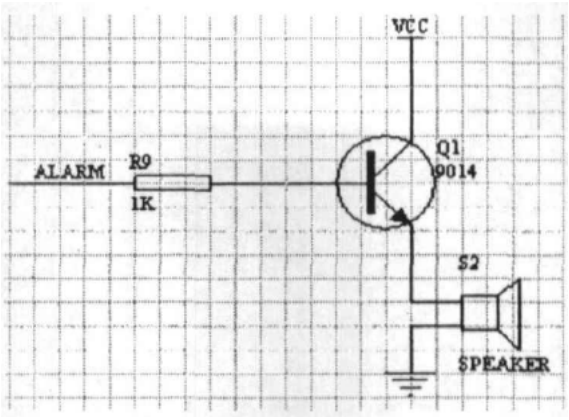

Figure 5: Alarm processing circuit

4. Software design

The system software program consists of main program, data acquisition and processing subroutine, display program and alarm program. The main program is the core of control and management. After the system is powered on, initialization and interrupt handling will be performed. The initialization mainly completes the setting of the alarm threshold and the initial check, meanwhile, the power supply of each appliance will be disconnected. After initialization, the system starts to work properly, such as formaldehyde concentration detection and alarm operation. The flow chart of the main program is shown in Figure 6.

Due to the indoor formaldehyde concentration will be relatively small, so the monitor range is set to 2 ppm. Its maximum input current is 400 nA, and after amplification, the output voltage range is 1.25~3 V, and the sensor is very vulnerable to the influence of electromagnetic interference, so when the system is debugged, we

should try to place far away from the interference source. When the system is powered, the formaldehyde concentration can be stabilized only after a slow change. After that, the sensor can measure the formaldehyde concentration in the air smoothly. In this system, the resolution of formaldehyde sensor is 0.02 ppm, because the formaldehyde sensor is affected by the external environment. In this paper, two time correction is adopted, and then piecewise linear interpolation is used to improve the accuracy.

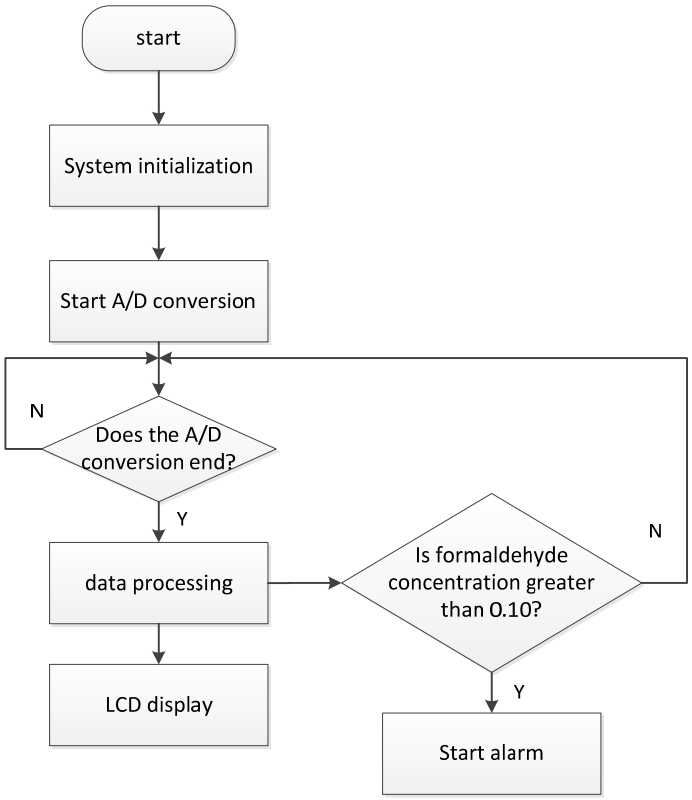

Figure 6 The flow chart of the main program

5. Experiment test

The standard indoor air quality testing instrument and the intelligent household air quality detection system designs based on STM32F107 are put into the room to detect and compare the formaldehyde concentration. The sampled data for the concentration of formic acid are shown in Table 1, and only 10 typical values are intercepted in the table. As shown in Figure 7, the data values of the formaldehyde measurements are approximately the same as the standard data values. According to the data analysis of different detection points the design of intelligent household air quality inspection system based on STM32F107 can control the measurement accuracy from -0.01ppm to +0.01ppm.

Table 1: Formaldehyde concentration test data

sampling point	standad value (ppm)	measured value (ppm)
1	0.02	0.02
2	0.04	0.04
3	0.05	0.05
4	0.07	0.07
5	0.12	0.13
6	0.17	0.17
7	0.21	0.22
8	0.28	0.29
9	0.38	0.38
10	0.45	0.46

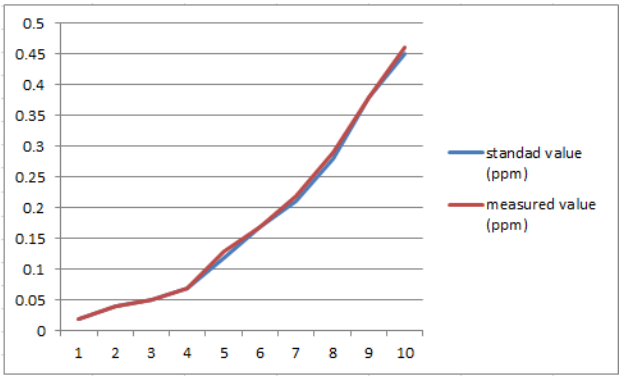

Figure 7: The comparison curve of formaldehyde concentration between standard value and measured value

6. Conclusion

An indoor formaldehyde automatic monitoring system designs in this paper which has the advantages of simple hardware structure, low power consumption, intelligent, high precision, simple operation and stable performance. The system realizes the function of monitoring, displaying, alarming and controlling the formaldehyde concentration in indoor air. The article uses STM32F107 single chip microcomputer to control system. First, a Dart sensor is used to collect formaldehyde signals. Then, the signal is amplified and processed by the LTC1049 data processing module circuit. On the one hand, the real-time value of formaldehyde concentration can be displayed by LCD12864. On the other hand, when the formaldehyde concentration exceeds the preset threshold, the buzzer will sound the alarm. Finally, the system realizes the real-time monitoring of indoor formaldehyde concentration. The experiment shows that the system has the advantages of good real-time, convenient operation, stable performance and intelligent. The system faces the general civilian market and has some practical significance in protecting people's health, safety and meeting the needs of life.

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