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Application of PM2.5 Alarm System Based on Embedded Technology in Urban Air Pollution Monitoring

Xi Wang

Software college, Nanyang Normal University, Nanyang 473061, China
nanyangwangxi@163.com

With the continuous improvement of people's living standard, people pay more and more attention to the environment. Air quality is an important indicator of the environment. Haze problems cannot be under estimated. It has brought an impact on the survival and development of mankind. However, PM2.5 is the leading cause of haze.PM2.5 has the characteristics of small volume, strong activity and easy to carry viruses and heavy metals, which has been greatly affected by the inhalation of the human body. Aiming at the problems caused by haze, this paper designs a PM2.5 alarm system, which aims to monitor the situation of urban air pollution. This paper uses STM32 MCU control system.PM2.5 sensor DSM501 is used to collect PM2.5 signal.LCD12864 liquid crystal display is used to display the real-time value of PM2.5 concentration and the current time. The speaker and the tricolor lantern are used to realize the function of limiting the sound and light alarm. The system realizes the real-time monitoring of PM2.5 index of urban air pollution. Experimental results show that the system has good real-time performance, convenient operation and stable performance. It realizes the monitoring and alarm function of PM2.5 in urban air, which brings convenience to people's life.

1. Introduction

In recent years, due to frequent occurrence of haze, people are increasingly concerned about the haze. Haze problem cannot be changed overnight, and the main pollutants haze is PM2.5. Therefore, it is urgent to design a PM2.5 monitoring device. According to the system monitoring results, people can take preventive measures in time, thereby reducing the harm caused by PM2.5. Firstly, the principle of PM2.5 concentration measurement is introduced. Then this paper introduces the hardware system design and software design of PM2.5 concentration monitoring based on STM32 microcontroller. Finally, the concentration of PM2.5 is obtained through the experimental test, and the monitoring and alarm function of PM2.5 in urban air is realized. The particulate matter emitted by human activities mainly comes from industrial production and living activities. They include fossil fuels (coal and oil) and biomass (plant straw and garbage etc.) (Nan et al., 2012). Vehicle exhaust emission is the main source of particulate matter. It is necessary to limit the emission of automobile exhaust, so as to control the emission of exhaust gas (Wang, 2013). The emission of automobile exhaust pollution has been one of the main components of PM2.5. The high quantity of motor vehicle makes the city air show the characteristics of compound pollution of soot and motor vehicle exhaust. Motor vehicle exhaust pollution has been high, and it has become one of the main sources of air pollution of PM2.5. In 1997, the government announce the implementation of air quality monitoring and air quality weekly in the National City municipalities and the capital city (Wu, 2000). In 2000, the state begins to implement the city's environmental air quality monitoring system for monitoring the construction of the project. At present, China's key cities have been carried out in the field of environmental air quality forecasting and daily work through the use of ambient air quality automatic monitoring system (Wu et al., 2005; Qi et al., 2000).
PM2.5 is also known as fine particulate matter with a diameter of less than or equal to 2.5 m particles, which can be suspended in the air for a long time (Yang et al., 2012). Epidemiological investigation of the health effects of ambient air particulate matter (PM) exposure in North America and Europe has been extensively studied (Schwartz, 1991; Schwartz, 1996). However, the effects of fine particulate matter (PM2.5), coarse particulate matter (PM2.5~10) and inhalable particulate matter (PM10) on human health are very different.

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PM2.5 can enter the lower respiratory tract of the human body, deposits in the lungs, and even through the alveoli into the blood. This phenomenon has serious harm to children with lung function growth (Cao et al., 1992). Based on the health hazards of PM2.5, the U.S. Environmental Protection Agency (USEPA) and the WHO have developed and revised their respective PM2.5 air quality standards or guidelines. At present, China's air pollution in large cities showing the characteristics of regional complex pollution (Beijing, Tianjin, the Yangtze River Delta, Pearl River Delta region as a typical representative), it is mainly manifested as a serious pollution of fine particles. These features will lead to lower the city's visibility and increase the frequency of occurrence of haze weather (Li et al., 2010).

China's urban air quality monitoring started relatively late. At present, three methods are used to monitor the air quality in China, which are instantaneous sampling method, continuous sampling analysis method for 24 hours and air quality automatic monitoring system (AQMS). The main monitoring factors of the instantaneous sampling method are SO2, TSP and NOX, which are sampled and monitored every 5 days in every season.30 minutes or 1 hours of gas are collected every morning, noon and night, and then detect it by hand. The sampling time is short, so it can not reflect the change rule of air quality completely and in real time. Therefore, with the development of the sampling technique, this method has been gradually eliminated (Zhang, 2001; Wang, 2008). 24h continuous sampling-laboratory analysis is the air quality of all day 24h continuous sampling and data analysis. This method can truly reflect the daily variation of urban air quality, get the average daily concentration, and the relative deviation is less than 10% (Zhang, 2001; Liu and Wang, 2001). At present, most of the cities in our country have established the air quality automatic monitoring system (AQMS). Air quality automatic monitoring system can monitor more projects, which are CO, NO, NO_2, SO_2, particulate matter, wind speed and wind direction, etc. At present, most of China's substation analysis instruments of the urban air quality monitoring system are able to independently analyze the gas concentration, through the data transmission device analysis of the data sent to the terminal (Wu, 2000). This monitoring method cannot be real-time on-line monitoring, but only a simple timing data collection.

2. Measuring principle of PM2.5 concentration

In China, there are three kinds of current PM2.5 detection methods, which are weighing method, betaray absorption method and micro oscillation balance method. The principle of the weighing method is to direct the PM2.5 to the membrane, and then weigh the balance. However, the filter does not collect all the PM2.5, and some of the very small particles can through the membrane. As long as the filter membrane for more than 0.3 micron particles greater than 99% of the interception efficiency, it is considered qualified. Beta ray absorption method, first of all, the PM2.5 is collected on filter paper, and then irradiated with a beam of beta rays. Then the light passing through the filter paper and particles due to scattering and attenuation, the degree of attenuation is proportional to the weight of PM2.5. The weight of PM2.5 can be calculated based on the attenuation of the radiation.

This paper uses optical dust principle to detect the concentration of PM2.5, which is the Lambert - Beer law. The content of the law is as follows: the incident light is parallel light and the light's intensity is I_0. When the incident light is absorbed by particulates with a length of L, the intensity of the emitted light can be expressed as:

$$I = I_0 \exp(-KcL) \tag{1}$$

Among them, I_0- the light intensity before the particulates to be measured; I-the transmitted light intensity after particulates absorption; K- absorption coefficient; C- measured particulates concentration; L-particulates length.

We transform the formula (1) to get:

$$c = \frac{1}{KL} \ln \frac{I_0}{I} \tag{2}$$

When the light passes through the measured material, the light intensity is weakened due to the scattering absorption. Therefore, the concentration of dust is measured by measuring the ratio of light intensity before and after the measured medium. From the above, we can see that if the light intensity is measured before and after absorption, the concentration of PM2.5 can be calculated.

3. System design

The principle block diagram of the PM2.5 detection system is shown in figure 1. This system take STM32 monolithic integrated circuit as the core, its peripheral circuit is composed of 4 modules, which are the PM2.5

density acquisition module, the signal processing module, the LCD 12864 liquid crystal display module and the sound and light alarm module. Each module is composed of each other to achieve the following functions. DSM501 sensor is used to obtain PM2.5 signal, and the PM2.5 signal will be transmitted to the STM32 microcontroller for digital processing. On the one hand, PM2.5 concentration data can be displayed through the LCD12864 monitor. On the other hand, the buzzer will alarm and the lights will flash when the PM2.5 concentration exceeds the predetermined value, in order to remind people to take preventive measures.

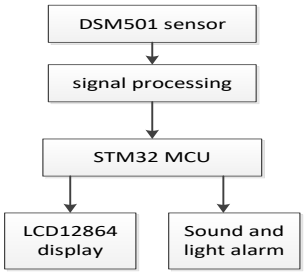

Figure 1: The principle block diagram of the PM2.5 detection system

3.1 PM2.5 detection sensor unit

PM2.5 is also known as fine particulate matter, usually defined in terms of aerodynamics as particles with diameters less than or equal to 2.5 microns. At the same time, the content of fine particles also represents the air quality, the higher the concentration of fine particles is, the worse the quality of the environment is. The module is mainly composed of DSM501 sensors, the use of laser detection principle to detect more than 1 micron dust particles. PWM pulse width modulation output and particle counting principle can be used to detect airborne particles with diameters of 1um or more. The internal air flow generator can automatically detect the surrounding air, and has the advantages of small size, light weight and easy installation. When the air is clean, the V_{out} output is high. When the pollutant concentration is too high, the output signal of V_{out} is low. Figure 2 shows the relationship between the low pulse rate and the number of particles.

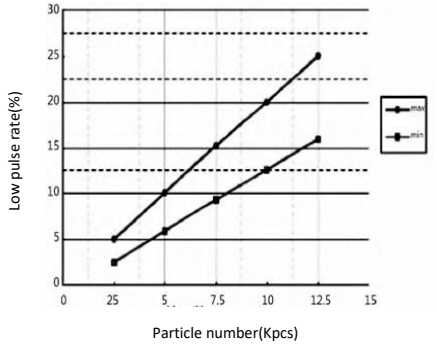

Figure 2: The relationship between the low pulse rate and the number of particles

3.2 Data processing module

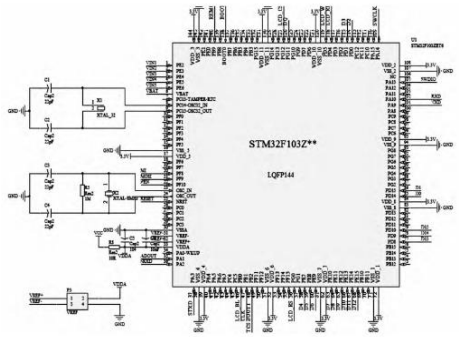

Figure 3: The smallest system of STM32

The data processing module mainly includes 3 parts, which are the amplifier, the filter and the embedded control module, and the embedded control module uses the STM32F103 monolithic integrated circuit. The STM32 series is based on the ARM Cortex-0 core designed specifically for high performance, low cost and low power embedded applications. STM32 is the core of PM2.5 detection system, which connects the other modules and controls the work of each module. First of all, the PM2.5 acquisition module sends the collected signal to the STM32 microcontroller after signal processing. Then the treatment of PM2.5 concentration data is displayed by the LCD display module. Finally, the alarm module is used to judge the concentration range of PM2.5, so as to realize the detection and early warning of the whole system. The smallest system of STM32 is shown in figure 3.

3.3 LCD display module

LCD display module is located in the PM2.5 concentration detection receiver, which is used to display the value of PM2.5 concentration and clock. This paper chooses LCD12864 as the monitor. The LCD12864 module is a dot matrix graphic LCD module with 4 bit /8 bit parallelism and a variety of interface modes of 2 wire or 3 wire serial interface. With a built-in ASCII of 8192 characters and a set of 128 characters, the display resolution is 128 * 64. By using the flexible interface of the module and the simple and convenient operation instructions, it can be used to form the Chinese human computer interactive graphic interface. Low voltage and low power consumption is another notable feature. Using a single + 5V or 3.3V power supply, the reset circuit contains a variety of control commands. In addition, it also has the characteristics of low price and high cost performance.

3.4 Sound and light alarm module

The sound and light alarm module is composed of three LED lights and a loudspeaker. When the STM32 port output is low, LED and speaker start to work. When the power is switched on, the alarm module starts to work. When the concentration of PM2.5 is normal, the green light is bright; when the PM2.5 concentration exceeds the pre-set value and starts to harm human health, the yellow light is bright; When the PM2.5 concentration seriously endanger the health of the people, the red light and the speaker alarm sound. The sound and light alarm circuit is shown in figure 4.

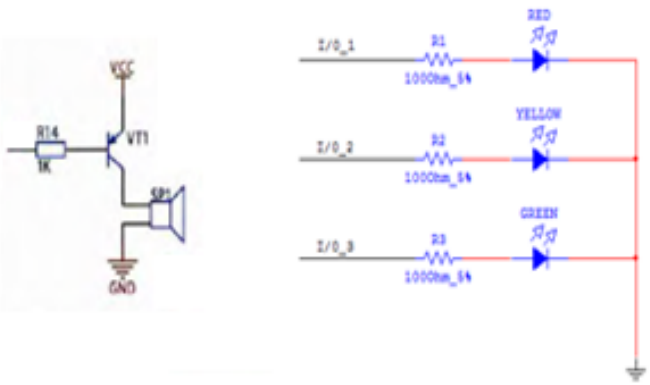

Figure 4: Sound and light alarm indicator circuit

4. Software design

The program design is based on embedded system STM32 microcontroller. It realizes the function of collecting, processing and alarm of PM2.5 concentration in urban air. The program design is composed of 5 parts, which are system initialization, sensor signal acquisition, data processing, LCD display and sound and light alarm. The system realizes the corresponding function by calling each subroutine. First of all, the system is initialized, which mainly includes timer initialization, interrupt initialization and LCD12864 initialization. The PM2.5 signal is collected by the DSM501 sensor, and then sent to the data processing module. The data processing program includes signal amplification, filtering and digital processing. Finally, the data of PM2.5 concentration are displayed by LCD. The LCD12864 display program displays the PM2.5 concentration value and the current time. The alarm program uses a timer to complete the control of the speaker and the indicator light. The system software design flow is shown in figure 5.

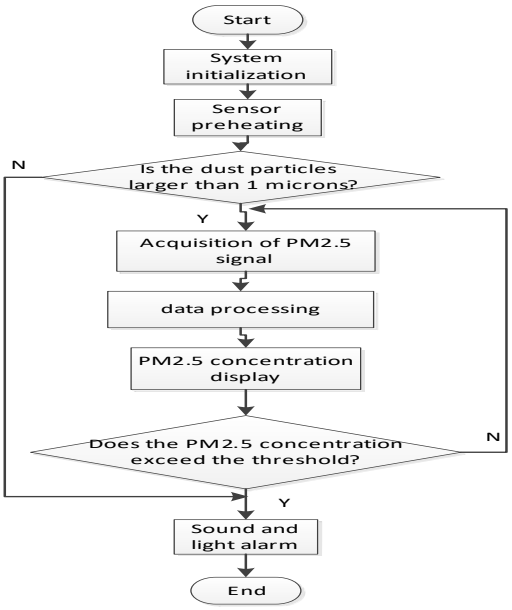

Figure 5: System software design flow

5. The experiment results

Table 1: PM2.5 monitoring data in different places in one day

Time	Residential (ug/m^3)	Shopping mall(ug/m^3)	Office building(ug/m^3)	Outdoor (ug/m^3)
00:00	38.3	35.9	52.8	56.7
01:00	42.4	29.5	49.2	48.9
02:00	41.9	31.9	42.1	36.5
03:00	46.7	38.7	48.9	39.3
04:00	49.8	43.1	57.4	45.4
05:00	54.9	50.6	63.2	50.2
06:00	69.2	57.9	68.9	84.8
07:00	78.6	65.8	79.8	113.6
08:00	92.3	77.5	83.2	159.4
09:00	97.1	88.6	86.1	164.3
10:00	99.9	97.8	93.0	172.6
11:00	118.4	123.7	124.5	198.7
12:00	119.5	126.5	128.4	205.3
13:00	115.3	118.4	112.4	190.4
14:00	116.7	120.1	103.6	183.6
15:00	88.5	92.6	85.7	144.9
16:00	56.7	76.7	65.3	72.9
17:00	53.9	91.2	72.1	85.8
18:00	65.2	88.8	93.5	107.4
19:00	68.5	81.0	98.4	124.5
20:00	52.8	59.7	85.6	93.8
21:00	46.3	53.2	74.8	82.8
22:00	43.5	47.7	60.4	71.4
23:00	36.8	39.8	57.3	67.5

The PM2.5 monitoring system is put into different places in a city to test, and the experimental results show that the PM2.5 concentration changes with time as shown in table 1. As can be seen from table 1, with the passage of time, the concentration of PM2.5 in the city gradually increased, and the outdoor PM2.5 concentration is significantly higher than indoor. The air quality grade PM2.5 standard value is defined as

follows: less than 75 (ug/m^3) is considered normal, 75~150 (ug/m^3)is defined as mild pollution, 150~250 (ug /m^3) is defined as severe pollution, and 250 (ug /m^3) and above is defined as serious pollution. According to the standard, the design of the system uses red, yellow and green lights to indicate the different concentrations of PM2.5. When the concentration of PM2.5 is less than 75, the green light is lit. When the concentration of PM2.5 in urban environment is more than 75 less than 250, the yellow light is illuminated. When the concentration of PM2.5 detected in the urban environment is greater than or equal to 250, the red light is lighted, and the alarm sound is sent out by the loudspeaker to remind the public to pay attention to the safety of travel. The system realizes the real-time monitoring of the change of PM2.5 concentration in urban environment.

6. Conclusion

In this paper, the real-time monitoring system of PM2.5 concentration based on embedded technology has the advantages of simple structure, low cost, high precision, low power consumption, simple operation and stable performance. The system can monitor, display, alarm and control the concentration of PM2.5 in the key environmental indicators of urban air. The utility model has the advantages of accurate measurement, good safety and strong applicability. This paper uses STM32 MCU control system. PM2.5 sensor DSM501 is used to collect PM2.5 signal. LCD12864 liquid crystal display is used to display the real-time value of PM2.5 concentration and the current time. The speaker and the tricolor lantern are used to realize the function of limiting the sound and light alarm. The system realizes the real-time monitoring of PM2.5 index of urban air pollution. The experimental results show that the system has the advantages of good real-time performance, convenient operation, stable performance and strong adaptability. It realizes the real-time monitoring, display and early warning of urban PM2.5 concentration, which is advanced and innovative.

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