# Design and Implementation of Portable Sensory System for Air Pollution Monitoring

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***Abstract*—Air pollution is increasingly serious now, leading to many environmental problems such as fog-haze weather phenomenon, which can do great harm to human health and even cause death. This paper focuses on the designing and fabrication of a portable sensory system for air pollution monitoring, which can detect the temperature, humidity, and particulate matter (PM), to reduce the harm of air pollution on people. This sensor mainly consists of a micro-programmed control unit, a temperature & humidity sensor DHT11, a dust sensor GP2Y1010AU0F, LCD, keys and LEDs. Ambient dust concentrations and temperature and humidity values will be displayed on the LCD, and the corresponding light alert signals and sound alert signals are emitted when the measured values are beyond their safe ranges.**

***Keywords— Air Quality; LCD Display; Temperature and Humidity Detection; Dust Detection.***

## I. INTRODUCTION

In the 21st century, due to the deterioration of air quality, haze weather phenomena are increasing, and harm is aggravated. According to the Economic Information Daily, haze is mainly composed of PM2.5, PM10, PM0.1 and heavy metals such as nickel, arsenic, chromium, lead. PM2.5 is a kind of particles smaller than 2.5 microns, only about one twentieth of the diameter of a human hair and can be entered into the lung. PM2.5 is richer in toxic and harmful substances and has a longer residence time in the atmosphere and a longer transport distance, compared with the course atmospheric particles. As a result, its impact on human health and the quality of the atmospheric environment is greater [1]. It can lead to many diseases on people such as cough and asthma, especially on those who are extremely sensitive to the dust, like the elderly, children and some patients [2]. Therefore, air pollution monitoring has attracted a lot of interest. The traditional air pollution monitoring stations use bulky and expensive instruments installed in limited areas, useless for people to monitor their surrounding environment in real time. Thus, the portable air quality sensors having the potential to fill in the gap left by traditional monitoring are required nowadays.

In the past few years, several techniques have been implemented to detect PM2.5 concentration. For example, PM2.5 can be collected on a filter paper and then irradiated with a beam of beta rays. When the ray penetrates the filter paper and particles, it is attenuated by scattering, and the attenuation degree is proportional to the weight of the PM2.5.

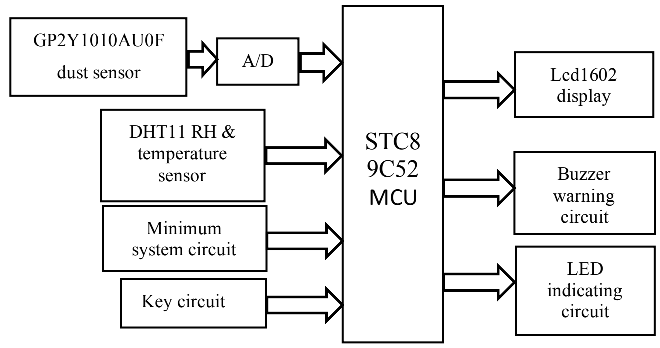



**Fig.1.** Scheme of the sensory system for air pollution monitoring.

The weight of the PM2.5 can be calculated by the attenuation of the ray. [3]

In this paper, an optical sensor for repeated detection of the dust pollution in real time will be introduced.

Preliminary results focus on the designing and fabrication of the air pollution sensor by utilizing a dust sensor and a humidity & temperature sensor. The system structure based on the two sensors is shown in Fig. 1. GP2Y1010AU0F dust sensor collects the concentration of PM2.5 in air while DHT11 sensor collects the humidity and temperature data, which is then displayed on LCD1602 liquid crystal through the processing by STC89C52, and the corresponding light alert signals and sound alert signals are emitted when these measured values exceed the safe ranges.

This paper is organized as follows: The sensors for air pollution monitoring are present in Section II, while the software design is given in Section III. The results of this sensory system are shown in Section IV. Finally, Section V draws a conclusion.

## II. HARDWARE

For the micro-programmed control unit, a single chip microcomputer called STC89C52 is adopted because of its low cost and high performance. It has eeporm function, 32 I/O pins, and can be processed in C language. However, it has no A/D conversion. Fig. 2 shows its encapsulation. The minimum system to make STC in normal operation state consists of STC and its necessary power supply, clock and reset circuits [4]. In this design, the 12MHz clock circuit and the automatic power-up reset circuit was used.

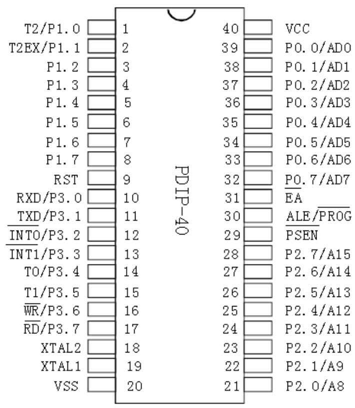



**Fig.2.** Pin diagram of STC89C52 [4].

In order to monitor dust concentration in the environment, an optical dust sensor GP2Y1010AU0F is used to measure fine particles with diameter of more than 0.8μm, such as cigarette smoke and pollen. This sensor not only detects the absolute number of particles per unit volume, but also can inhale the external air with a built-in airflow generator. Infrared LED and photo-transistors are diagonally mounted inside this sensor, enabling it to detect the reflected light from dust in the air. It has small volume, high sensitivity, long service life, and good stability [5]. Table I summarizes the basic information of it.

**Table 1.** Main parameters of GP2Y1010AU [5]

| Main Parameters | |
|---|---|
| Sensitivity | 0.5V/(0.1mg/m$^3$) |
| Output voltage at no dust | 0.9V (TYP) |
| Consumption current | 11mA (TYP) |
| Operating temperature | -10~65℃ |

Since it is an analogue sensor, a A/D converter ADC0832 is required to convert the voltage signal into a digital signal processed by STC, as shown in Fig. 3. Its output voltage is proportional to the dust density. In the normal living conditions, the dust density in air is normally 0 ~ 0.2 mg/m$^3$.

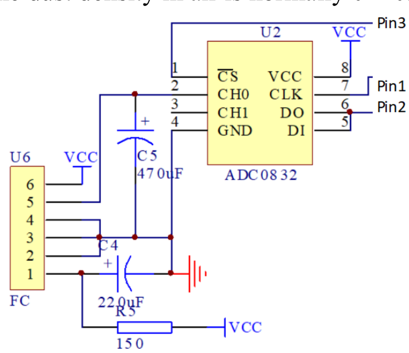



**Fig.3.** Dust detection circuit. A 150Ω resistor is required to limit the current and a 220μF capacitor is also needed to stabilize the power supply of infrared LED [5].

DHT11 is a temperature and humidity sensor with digital signal output. It has 4 pins, in which the DATA pin is used for communication with MCU. The circuit is shown in Fig. 4. A complete data transfer is in 40 bit, including 8-bit humidity integer and decimal data, 8-bit temperature integer and decimal data, and 8-bit Checksum [6]. In this design, only the integer parts of both humidity and temperature is displayed on LCD. The information of DHT11 is shown in table II.

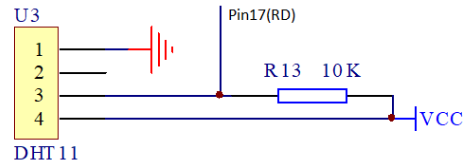



**Fig.4.** RH and temperature detection circuit. A 10K pull-up resistor is added between DATA pin and power supply since the connecting cable is shorter than 20 meters [6].

**Table 2.** Information of DHT11 [6]

| Measuring range | Humidity measurement accuracy | Temperature measurement accuracy | Resolution |
|---|---|---|---|
| 20—90%RH 0—50℃ | ±5%RH | ±2℃ | 1 |

Additionally, LCD1602 was adopted to display the values. It can display 2 rows of 16 characters or numbers, has built-in standard ASCII character code, and can be controlled by command code to display characters or flashing cursor. In this design, it will show different contents once each key is pressed, and the flashing cursor is also displayed during the process of safe range adjusting.

The LCD1602 shown in Fig. 5 has 16 pins, including 8 data buses D0 to D7 connected to P0 port of SCT89C52, and three control ports RS, R/W, EN connected respectively to pin28, pin27, pin26 of the single chip [7]. VL is the contrast adjusting port, and the contrast is the weakest when connected to the positive power supply, while it is the highest when grounded. Programming mainly uses the three control ports to initialize, write commands, and write data, that is RS (command or data), R/W (read or write), and E (enable), whose corresponding program is written according to the sequence diagram.

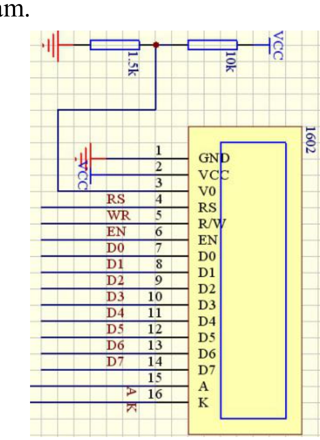



**Fig.5.** Schematic diagram of LCD1602. As P0 port of STC89C52 cannot output the high-level signal, pull-up resistors of 10k are needed to pull up the voltage to 5V. When the contrast is excessively high, the "ghost shadow" will be produced, so the contrast might be adjusted by a 10K potentiometer [7].

In terms of light indicating section, the use of LED with different colours indicates the different air condition in this design. When temperature is above or below its safe range, a red or green LED lights up. When humidity is above or below its safe range, a yellow or blue LED lights up. When dust concentration is higher than its maximum, a pink LED light up. The circuit is shown in Fig. 6.

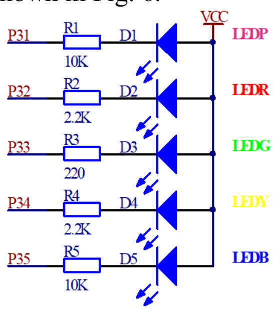



**Fig.6.** Light indicating circuit. Current limiting resistors with different values are used to realize the same light intensity of each LED in different colour.

In terms of sound alert section, an active buzzer is used to make a sound when there is any LED on. The circuit is shown in Fig. 7.

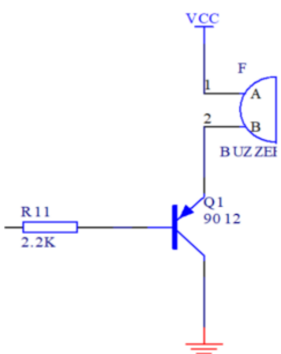



**Fig.7.** Sound alert circuit. The active buzzer will make a sound when a DC voltage is applied to both ends of it.

For keyboard section, three keys are used to adjust the safe ranges. One is used to enter the adjustment interfaces and to select the parameters in turn, the other two are used to increase and decrease the values respectively.

## III. Software

The main function of the software is to realize the data acquisition of the sensor signal, and then carry out the data calculation, analysis, LCD display and alert function. Fig. 8 shows the block flow diagram of the program. At the beginning of the program, the system is initialized, including the LCD display module and interrupt system. After that, the CPU waits for the start signal and then starts to convert and read humidity and temperature data. Then light related LEDs if these data exceed limited values. A/D conversion is then executed and read the dust data, then also light related LED if the data exceeds limited value. In the end, the buzzer will make a sound if any LED is on.

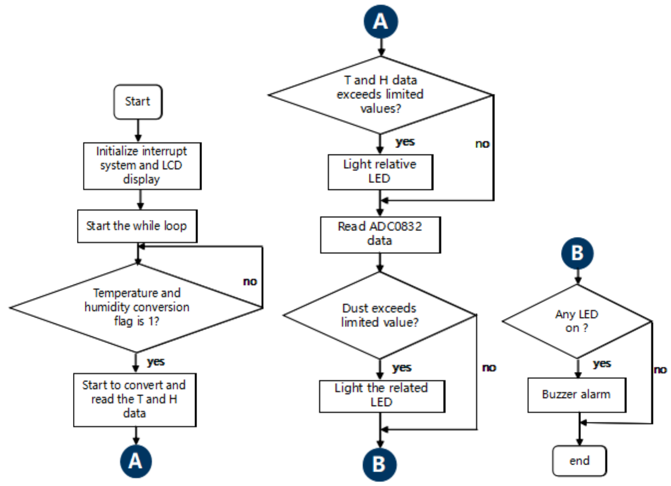



**Fig.8.** Block flow diagram of the program.

## IV. Experimental Results

The programme can be simulated and debugged by using Keil C51. It is used to monitor the running status of each module. After debugging is completed, the program is imported into it for simulation using Proteus, and the simulation results are shown in Fig. 9. It is clear that the programme and the schematic circuits are both in good performance. The temperature is higher than TH and the PM is higher than its threshold, so the related dust warning LED and high temperature warning LED lights on.

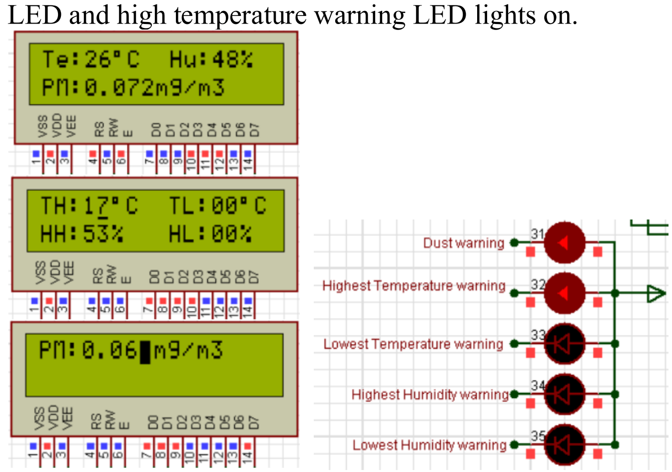
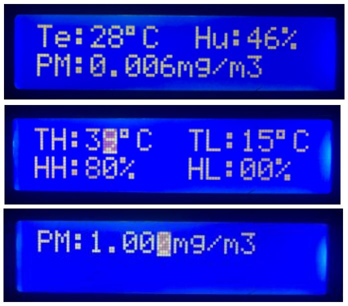



**Fig.9**. Simulation results of (left) LCD display and (right) LED indicating.

For the final product, the LCD displays the measurements correctly, directly and intuitively as shown in Fig. 10. The humidity and temperature has relatively accurate values, whereas the displayed dust concentration is inaccurate regularly because its output can be easily influenced by the external conditions, such as mechanical oscillation and adhered dust inside the sensor [5]. The key circuit works well, since the parameters can be selected and value-adjust easily and quickly by keystrokes. Furthermore, the alert circuits are also in good performance, as the buzzer is able to make a sound and the related LEDs can light in different cases.




(a)
(b)
(c)

**Fig.10.** LCD display results. (a) is the measurement values display interface, (b) is the threshold value setting interface of temperature and humidity, and (c) is threshold value setting interface of PM value.

When the power is on, the LCD will display the temperature value, humidity value, and PM value firstly as shown in (a) of Fig. 10.

When key1 is pressed once, the threshold value setting interface for temperature and humidity is displayed and the flashing cursor is flickering at the first row, fifth column of LCD as shown in (b) of Fig. 10. When key1 is pressed twice to the fourth time, the flashing cursor is moving to the 5th column of the 1st row, the 14th column of the 1st row, the 5th column of the 2nd row, and the 14th column of the 2nd row respectively. This value is changed by 1 each time key2 or key3 is pressed, and the highest values (TH, HH) must be at least 1 more than the lowest values (TL, HL). The highest values should be no more than 99, while the lowest values should be no more than 98, and then return to 0.

When key1 is pressed the fifth time, the threshold value setting interface for PM is displayed and the flashing cursor is shown at the 8th column of the first row as shown in (c) of Fig. 10. This value is changed by 0.010mg/m3 each time key2 or key3 is pressed and must be no more than 1.000mg/m3.

When key1 is pressed the sixth time, the first interface showing all the temperature value, humidity value, and PM value is shown again and loop this whole process.

Compare to the traditional air pollution monitoring stations, this design has advantages including a good man-machine dialogue interface, a low cost, the portability, humanized acousto-optic alarm function and memory function, and the ability to monitor surrounding air pollution in real time.

However, it also has drawbacks such as the unattractive appearance, and inaccurate PM values regularly. Additionally, it can detect very few components of air pollution, leaving it less multifunctional and practical sometimes, and the results are not intuitive enough for normal users who rarely know about the relationship between the measurement values and the air quality.

## V. Conclusion

In this paper, an automatic monitoring system for air pollution with simple operations, small size and low cost is designed, simulated and fabricated. It can detect the temperature, humidity, and particulate matter, whose vales are displayed on the LCD, and the corresponding light alert signals and sound alert signals are emitted when the measured values are beyond their safe ranges.

A lot of practical skills about digital sensor, analog sensor, single chip microcomputer, A/D converter, LCD display, and buzzer circuit have been acquired. The hardware test involves the use of multimetre, and the software design involves the application of Keil programming and Proteus simulation.

Nowadays, existing air monitoring stations are based on bulky and expensive instruments installed in limited areas. This portable sensor can detect surrounding air pollution in real time, which can be widely used in the family or personal monitoring of air pollution in some private places.

There is also some further work could be done on this design. Another dust sensor with higher sensitivity could be adopted to increase the reliability of this device. In addition to PM2.5, there are also many gases that cause air pollution, such as NO, SO2, O3, and VOC, which could also be detect in later design.

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