Design of PM2.5 Air Quality Detection System based on Median Value Average Filtering Algorithm and OLED Screen

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Abstract. Environmental pollution problems are becoming more and more serious, air pollution and air quality problems, has become a hot spot of special concern. PM2.5 is an important indicator of air quality testing. This design uses GP2Y1010AUOF dust sensor, SHT20 temperature and humidity sensor and so on, transmit the signal to ATMEGA328PAUM SCM. The system detects the detection through the analog to digital conversion and median value average filtering algorithm. The PM2.5 Concentration values are displayed to OLED screen, alert if the detection value exceeds the standard. Experiments show that the system is running well, with a measurement accuracy of 4.8%, and has a certain stability and practicality.

Keywords: Sensor technology; filtering algorithm; OLED screen; PM2.5.

1. Introduction
The various environmental in recent years are reasons makes people's attention to environmental quality become higher and higher. Journalist Chai Jing released the documentary "Under the Sky" on 28 February 2015, introducing the seriousness and hazards of the haze problem, environmental pollution and the topic of PM2.5 are hot topics. PM2.5 refers to ambient air, aero dynamic equivalent diameter less than or equal to 2.5microns. The particulate matter, the human respiratory system cannot be immune, its particulate matter can directly into the lungs, even to the alveoli, the harm is enormous.

Foreign air environment detection is mainly developed by light scattering, light absorption, AC electrostatic sensing and other principles of testing instruments, the core of the system is a microcontroller or PLC (Programmable Logic Controller) [2], the main component is a sensor, forming a multi-functional detection platform. The purpose of this paper is to design a small portable device that integrates PM2.5 detection, temperature and humidity detection and clock display to facilitate the detection and observation and study of air quality changes around you.

2. System structure design
This design is a combination of microcontroller digital control technology and sensor technology, using a modular design scheme, the system architecture diagram as shown in Figure 1. Mainly included ATMEGA328P-AU microcontroller module, SHT20 temperature and humidity sensor module, dust sensor module, DS1302 Real-time clock chip, OLED liquid crystal display module, alarm module, external crystal and reset circuit.
In order to achieve temperature and humidity, air PM2.5 monitoring as one of the environmental quality testing system. In this paper, the ATMEGA328P-AU microcontroller is the main module, responsible for sending instructions, A/D conversion, algorithmic operations, output display, storage variables, etc. GP2Y1010AUOF, the sensor collects air dust particle data and transmits it back in a voltage-value simulation ATMEGA328P-AU microcontroller; After A-D conversion, the system obtains a set of digital data, using filtering algorithm for data processing and calculation, so as to obtain a more realistic and objective PM2.5 detection value.

![System architecture diagram](image)

**Figure 1. System architecture diagram**

3. Hardware design

This design uses the Arduino uno R3 core board as the development microcontroller, and its MCU is an ATMEGA328P-PU chip, which is integrated six of Independent ADC Simulated inputs and six of PWM digital output, PM2.5 dust sensors and so on, the devices are connected to their devices.

3.1. PM2.5 dust sensors

This design uses a GP2Y1010AUOF optical air quality sensor, which is constructed diagonally with infrared light-emitting diodes and phototransistors to detect dust reflection in the air. It has the following characteristics: 0.5V/(0.1mg/m³), very small tobacco smoke particles can be detected, voltage stabilization, added 150 ohm serial resistance and a220micro-aluminum electrolytic capacitor ground form a resistance filter to stabilize the voltage, and11mA is consumed when working, very energy efficient, small in size and light weight.

3.2. Infrared remote control

This design uses an integrated remote control with infrared light-emitting diodes and an IR1838 integrated infrared receiving head as an infrared Remote-control module. The IR1838 inherits internal circuits that include infrared monitoring diodes, amplifiers, limiters, band-pass filters, component circuits, and comparators. Infrared remote control uses infrared light-emitting diodes to emit modulated carrier infrared, and then the receiving device captures the signal through the infrared receiving head, and obtains instructions through amplification circuit and decoding coding.

3.3. Temperature and Humidity Module

The temperature and humidity sensor is used with the Swiss company Sensirion's SHT20, SHT20 with a double-column flat and no pin DFN for reflow welding Package, operating power is very low, even in high humidity environments, can be more stable operation. It is characterized by the following: using standard I2C digital signal communication; Humidity accuracy resolution 12-bit, temperature resolution 14-bit; In the 8-bit measurement; In the 1 second/time case, Power consumption: 1.5uw.
3.4. Real-time clock module
The design is based on the DS1302 real-time clock chip of America Company DALLAS, and its application schematic is shown in Figure 2. Dual power design: main power VCC1 and backup power supply VCC2, power supply share GND. With 32.768KHZ crystals on the XTAL side, the XTAL side provides parameters such as seconds, minutes, hours, days, weeks, months and years in real time, with leap year compensation.

![DS1302 Application schematic diagram](image)

**Figure 2.** DS1302 Application schematic diagram

3.5. Display module
The display module features a 16-column, 2-line character LCD1602 backlit LCD screen and 27mm x 28mm OLED has a combination of electromechanical laser displays, and the LCD1602 uses an IIC bus to better display PM2.5 concentration value and alarm value. And OLED has 128x64 Display accuracy, viewing angle up to 170 Degrees [5], its hardware diagram, as shown in the figure 3., its Communication adoption 4 Lines SPI, brushing fast, can clearly displaying PM2.5 Concentration, temperature and humidity, and real-time clock data. The experimental results show that the display effect is well.

![OLED Display Screen](image)

**Figure 3.** OLED Display Screen

4. Algorithms and software design
Because the acquisition of PM2.5 belongs to the continuous acquisition type in a short period of time, in order to solve the problem that the collected data cannot be the same in real time, the median value average filtering algorithm is adopted. In order to be accurate to ug/m3 level, the value of the median value average filtering algorithm is added to the weighted push average filtering algorithm, which has a good inhibition effect on interference deviation. The software is designed to be programmed with Arduino IDE 1.6.5 for the master chip AT328P-AU, using Atium Designer 6.9 for circuit diagram drawing and PCB board design.
4.1. Algorithm design
Since the PM2.5 concentration in the air is a change over time, there is instability, in order to obtain more accurate and objective concentration data must go through a certain filtering process. This design uses the median value average filtering algorithm, which combines the advantages of median value filtering method and arithmetic average filtering method to make it. This is done by continuously sampling much PM2.5 data, putting the maximum and partial of them (2/n) and minimum value will be deleted, and the arithmetic average of the N-n data is calculated. The algorithm flowchart is shown in Figure 4.

![Figure 4. Average filtering algorithm flowchart](image)

In order to be accurate to the ug/m3 level, and in a short period of time the air PM2.5 value changes large and unstable situation, the median value average filtering algorithm after the weighted push average filtering algorithm. Its table shown in (1)

\[
  I = \frac{I_{\text{high}} - I_{\text{low}}}{C_{\text{high}} - C_{\text{low}}} \left( C - C_{\text{low}} \right) + I_{\text{low}}
\]

**PS:** I represents air index; C represents contaminant concentration
Clow represents less than or equal to the limit of pollutant concentration C;
Chigh represents a concentration limit greater than or equal to C;
Ilow represents the exponential limit corresponding to Clow;
Ihigh corresponds to the exponential limit of Chigh.
It is used by treating the continuous take N sample values as a queue, the length of which is fixed to N, and a new PM2.5 data collected each time into the end of the queue and throw away the original team leader's first data (first in-first out principle). A weighted arithmetic average of N data in the queue results in a new filter.

4.2. Software and PCB Design
This design uses the Arduino IDE 1.6.5 software design master chip ATMEGA328P-AU program, some of which are shown in the picture 5. The SHT20 temperature and humidity sensor captures ambient temperature and humidity, and sensor data can be sent to the MCUATMEGA328P-AU via COM serial. The ATMEGA328P-AU microcontroller receives the analog signal from the sensor and carries the analog signal through the internal converter for A-D conversion. After obtaining a set of digital data,
The currently detected PM2.5 concentration data value, temperature and humidity, clock date and other
information will be displayed by means of a 0.96-inch monochrome blue-OLED LCD display after data
analysis, processing and calculation using a filtering algorithm. If the detection value exceeds the set
alarm value, the buzzer will assert an alarm.

Figure 5. Arduino IDE GUI

The PCB board design and circuit diagram design use Atium designer 6.9 to integrate all components
on the PCB, eliminating excessive jump wire connections. The aspect ratio of the board is 1:0.68, which
is in line with the gold ratio. Where J2 is the buzzer, FM1 is the button battery, and the communication
between the sensors uses COM serial communication.

Figure 6. PCB Design Chart
5. System implementation and testing

This system test carried out black box testing and threshold testing. Black box testing focused on the external structure of the program, regardless of the internal logical structure, mainly for the software interface and software features to be tested. The threshold test is basically consistent with the value calculated by the expected reference characteristic curve. Experiments show that the threshold and reference characteristic curve value are basically the same, and the PM2.5 alarm signal can be issued.

5.1. Black Box Test

In order to verify the operation of the system, this paper uses a black box test to compare the measured values of the captured PM2.5 with the official given PM2.5 reference value. As shown in Figure 7, the official detection value of local PM2.5 air quality is approximately 61ug/m3.

![Screenshot of official data](image)

As shown in Figure 8, the measurement test ingress environment for detection in outdoor ventilation conditions, size is 57ug/m3. Through several actual tests before and after the test, the instrument measured the data value of PM2.5 and the official data gap deviation control at plus or minus 3ug/m3, the measurement accuracy of the 4.8%, the system operation has a certain degree of reliability and stability, the operation process is basically in line with the preset situation.

![Outdoor Test Photo](image)
5.2. Overall running test of the system
The circuit board is designed PCB, by the board manufacturer stoic manufacturers, and electronic components welded. Designed with acrylic plate as the equipment packaging, acrylic plate unit, the upper and lower two layers are fixed with copper column screws, to get the overall operating module, the front of the system as shown in the figure 9 module measurement is convenient, portable use.

![Figure 9. The Front View of Measurement System](image)

6. Summarize
In recent years, smog weather and haze concentrations in various regions have aroused widespread concern, and PM2.5 is an important measure of air quality. Safety, transportation and other fields of measurement and universal application. In this paper, a simple PM2.5 ambient air quality detection device is formed by combining an air sensor and a microcontroller combined with an OLED screen. The PM2.5 value and current temperature and humidity are collected, calculated, displayed and alerted using a modular design scheme. Using a combination of filtering algorithms, the collected sample values are effectively processed, so as to obtain a more accurate and objective PM2.5 concentration value. This design and method provides reference and convenience for people to understand and monitor air quality, the system cost is low, the measurement accuracy is high, can meet the current requirements of air quality monitoring.

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