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Design of On-line Monitoring System for Dust

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Abstract: An online monitoring instrument based on Arduino microcontroller is designed, which can detect the PM2.5 concentration and noise in real time and display it on the local OLED screen, and transmit to the cloud platform through the WiFi network for remote monitoring. The key part of the design is how to design the hardware and how to communicate with the cloud platform through the network. First, by consulting relevant information, analyzing the current situation at home and abroad, then choosing the components of each module, and finally determining the solution of the hardware part, the hardware part is used as the core processor of Arduino microcontroller , and the whole system consists of detection, display, communication and other modules. Completed the hardware construction and software debugging of the online monitoring device for dust, and established communication with freeboard cloud platform website.

Keywords: PM2.5 ; single chip microcomputer; cloud platform; WiFi network

INTRODUCTION

According to the authorities, 15% of the Beijing's PM2.5 levels came from the pollution of the dust, and the pollution of the dust is the largest of all the pollution in Nanjing, reaching 37 percent [Zhang Tao, *et. al.*, 2017]. Such serious dust pollution has attracted the attention of governments at all levels. Various measures have been taken to strictly prevent and control the dust pollution, such as installing spray dust removal equipment, video monitoring probe and other devices. People should not only control the pollution that has been produced, but also do a good job in preventing the dust pollution in advance [Lan Bingxin, *et. al.*, 2014]. Therefore, how to monitor dust pollution and realize early warning is the most important task. In order to effectively manage the dust pollution on the construction site and improve the environmental quality, it is necessary to install the dust online monitoring system on the construction site. At present, the existing system mainly has many disadvantages, such as single measurement parameters and complex wiring, etc. In order to solve the shortcomings of the existing technology, this design USES single-chip microcomputer to design an online dust monitor, which can collect noise and PM2.5 parameters, complete the local display and upload to the cloud platform through WiFi network.

SYSTEM STRUCTURE

The topic of this design is the design of dust online monitoring system, dust online monitoring instrument is mainly composed of four main parts: microcontroller minimum system, detection module, display module and communication module. MCU minimum system consists of MCU, reset circuit and power supply, etc., as shown in figure 1, it is the core control system of the whole system, responsible for receiving information uploaded by the detection module, control display module, control communication module and a series of tasks [Bian jinliang, *et. al.*, 2014]. The detection module needs to accurately and real-time detect PM2.5 concentration and noise decibel value. The display module needs to display all kinds of information. In the design, it is required to display not only PM2.5 concentration, but also noise decibel value. The communication module needs to transmit the collected data to the cloud platform through the network, so as to realize synchronous monitoring of PM2.5 and noise.
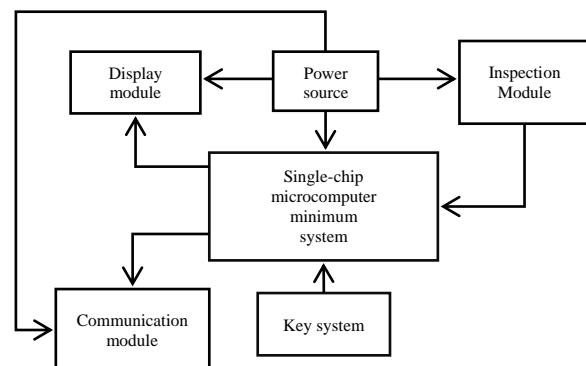

FIG. 1 Overall scheme design block diagram

HARDWARE DESIGN

Microcontroller minimum system design

The minimum single-chip microcomputer system design mainly includes: ATMEGA328P_32LQFP microcontroller, power interface, crystal oscillator circuit and reset circuit, of which the ATMEGA328P_32LQFP microcontroller as the main

core part; The power interface is used to provide +5V power to the MCU minimum system. The crystal oscillator circuit is used to record the program of single chip microcomputer. It plays an important role in the completion of program and hardware docking. Reset circuit is the reset button in the system, in case of program error, etc. The design circuit of the microcontroller minimum system is shown in figure 2.
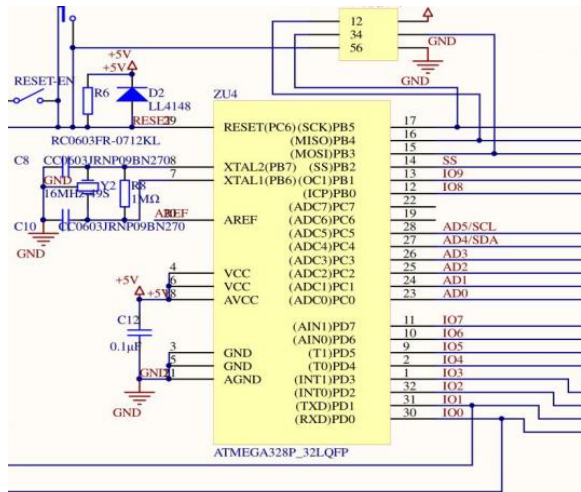

Fig. 2 minimum system circuit diagram

Arduino Uno R3 is a microcontroller development board with ATmega328 microprocessor as the core. The development board consists of fourteen digital input/output pins and six analog inputs. A 16MHz quartz crystal oscillator, a USB port, a power connector, an ICSP plug and a reset button. Uno contains all the necessary elements for microcontroller operation. Use a USB cable to connect to your computer, or use an AC-DC adapter or battery powered.

Input and output: pins 0 and 1 are used to receive and send serial data. Pins 2 and 3 can be configured to issue an abort command when a low value, rising or falling edge occurs. Pins 3, 5, 6, 9, 10, and 11 provide 8-bit PWM output through the analog write function [Łukasz, et. al., 2014]. Pins 10, 11, 12, and 13: these pins support SPI communication through the SPI library. Pin 13: there is a built-in LED connected to the number 13 pin. When the pin is at high power, the LED lights up, and when the pin voltage is low, the LED goes out. A4 and A5 pins: twins communication is supported through the circuit library.
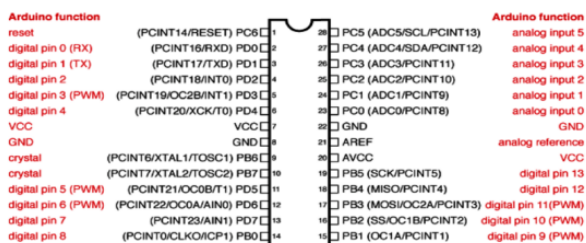

Fig. 3 Arduino Uno pin diagram

Crystal oscillator circuit: Arduino Uno microcontroller generates clock signals in two ways: internal clock and external clock. The internal clock is the internal oscillator circuit in the microcontroller. The external clock circuit needs to be externally connected between the XTAL1 and XTAL2 pins of the microcontroller. A crystal oscillator constitutes a self-oscillating circuit which can generate a clock pulse signal outside the microcontroller. Capacitors C8 and C10 in the figure range from 5 to 30 pF, usually 30 pF. The frequency of the crystal is 16MHz. The crystal oscillator circuit is shown in figure 4.
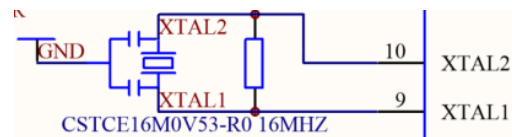

Fig. 4 crystal oscillator circuit diagram

Reset circuit: the principle of reset circuit is that when the REST pin of Arduino Uno MCU inputs a high level and maintains two or more machine cycles, the microcontroller will perform the reset operation. The most common reset methods are automatic power reset and key reset. In this design, the key is reset. After the microcontroller is started for 0.1s, the voltage at both ends of capacitor C is continuously charged to 5V, so the voltage at both ends of 10K resistor is close to 0V, and RST is at a low level, so the system works normally. The switch is on when the button is pressed. At this point, the capacitor at both ends of the formation of a circuit, the capacitor short circuit. Thus, as the button is pressed, the capacitor begins to release charge. The voltage of the capacitor varies from 5V to 1.5v within 0.1s. At this point, the voltage on the 10K resistor is 3.5v, so the RST pin receives the high level, and the system will automatically reset.

Display module design

The display module adopts OLED12864 liquid crystal display screen, and its internal Chinese library contains national standard level 1 and level 2 Chinese character library, which can display Numbers, characters and patterns, etc. It is convenient to use, and directly USES 5V power supply, which can directly match with Arduino Uno MCU I/O port level. OLED12864 working principle and process of liquid crystal display: R/W, E, D/I represent 12864 oled LCD screen, speaking, reading and writing control, that can control and command control port data selection, connect the three pin respectively to the Arduino Uno microcontroller, can realize the control of single chip microcomputer 12864 oled LCD display, data mouth D0 to D7 P0 port connected to the MCU, realizes the single chip microcomputer and OLED12864 communication with each other. Where, 1 pin is connected to GND, and 2 pin is connected to positive 3V power supply; 3~7 pins are connected to 6 reset pins in MCU jumper interface JP1 and 2~5

pins in JP2 respectively to realize data transmission to MCU. The display module circuit is shown in figure 5.
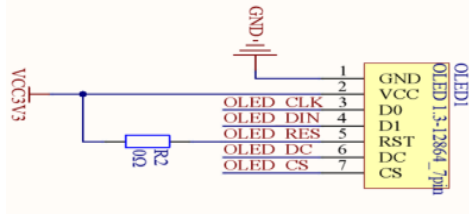
Fig. 7 circuit diagram of noise sensor(right)

Fig. 5 the module circuit diagram

Design of detection module

The monitoring module consists of a high-sensitivity microphone (noise) sensor module and a sharp optical dust (PM2.5) sensor. The integration of the two is of high precision and low cost, which can save PCB space, accurately collect PM2.5 and sound decibel, and transmit signals with high speed and precision. The 1-pin and 6-pin of the PM 2.5 sensor will be connected to + 5v power source, two draw feet and a 4-pin grounding, and the 3-pin jumper is connected to the network's mark number 2,and the 5-pin jumper is connected to the network's mark number A0.

JP3 5-pin of the jumper interface of the noise sensor 1-pin; 2-pin connected with GND; 3 pin joint +5V; In AD, the network label is used to realize the data transmission between the connection and MCU.

The high-sensitivity microphone sensor module has two outputs:

(1)AO: analog output, real-time output of microphone voltage signal;

(2)DO: when the sound intensity reaches a certain threshold, the high level signal is output.

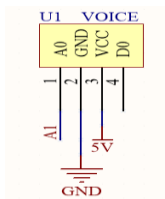Module features: 5V dc power supply, analog output, threshold level output.

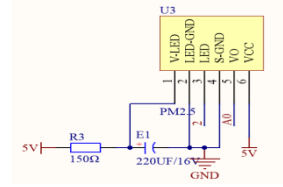Fig. 6 circuit diagram of PM2.5 detection sensor(left)

Design of communication module

ESP8266 has two read-only memory schemes. The first scheme can modify the parameters of read-only memory by using at command. If this scheme is adopted, the parameters of the chip can be modified by using at command [Manuel, et. al., 2014] . The second is the read-only memory scheme of the Internet of things. This read-only memory scheme can configure the GPIO of ESP8266. By using commands, ESP8266 can also collect data collected by many sensors and upload them to the network.

The pins 4 and 8 of ESP8266 are connected to the pins 6 and 7 of the jumper interface JP4 (sending and receiving) to complete the data sending and receiving; 1 pin for GND, 7 pin for VCC. The data collected by pm2.5 sensor and sound sensor are received through 8-pin and then sent to the cloud platform through 4 pins. It is mainly through the mobile phone hotspot connection to achieve the purpose of the network, the first mobile phone hotspot open, set the network name as dzD, password as 20190227, security setting WPA2 P5K. Then start the online dust detector, after a short delay, the display screen detection data, so ESP8266 successfully achieved the purpose of mobile phone data sent to the cloud platform.
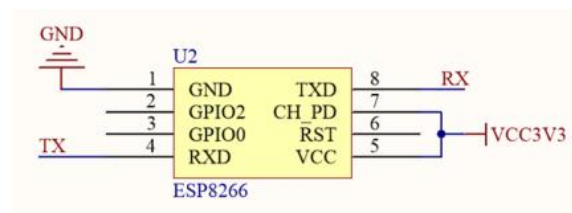
Fig. 8 ESP8266 circuit diagram

SOFTWARE DESIGN

Main program design

Dust monitoring instrument online of the main program flow is that when the dust monitoring instrument online of electricity, first using the C program to realize the WiFi library function, OLED library function call, start preliminary running system initialization, if there is no hardware serial port, the pin is used to realize soft 6/7 (0/1 two pin is the hardware serial port), serial port call serial interface library functions (RX: receiving, TX: send) and an external module (detection module, display module, communication module) and dweet set parameters such as execution, the program execution of the loop. The external module (detection module, display module, communication module), dweet setting and

other parameters shall be executed, and the collection and display of sound signal and PM2.5 signal shall be repeated, and the data and display shall be sent to the cloud platform by using ESP8266 module. The flow chart of the main program is shown in figure 9.

```
┌─────────────┐
│    Start    │
└─────────────┘
       │
       ▼
┌─────────────┐
│   Initial   │
│ subfunction │
└─────────────┘
       │
       ▼
┌─────────────┐
│ PM2.5 detection │ ◄──
│  subroutine │
└─────────────┘
       │
       ▼
┌─────────────┐
│ Noise detection │       No
│  subroutine │
└─────────────┘
       │
       ▼
    ◇─────────◇
   Is there data entry?
    ◇─────────◇
       │ Yes
       ▼
┌─────────────┐
│  According to │
│ the function │
└─────────────┘
       │
       ▼
┌─────────────┐
│  WiFi data  │
│ transmission │
└─────────────┘
```
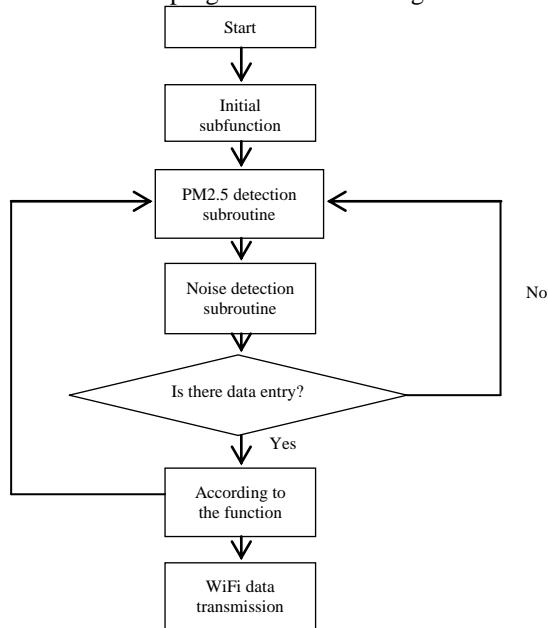
Fig. 9 flow chart of main program

Dust particle distribution correlation algorithm

The dust piled up in the open air is carried over and dispersed by the wind, and the dust source flow can be seen as gas-solid two-phase flow composed of gas and particles. Is used for the particle Phase under though laser coordinate, slip along their own orbit, with the air of discrete medium model (DisCrete Phase Mode, DPM) processing, and follow PSIC (Particle Source in Cell Method) algorithm, considering the air at the same time, the role of dust dust particles also take into consideration to the effects of gas Phase flow field, the discrete particle relative to the role of continuous gas fluid as air mass, momentum, turbulence kinetic energy and turbulent kinetic energy dissipation rate conservation equation in the additional Source term. The runge-kutta method is used to calculate the particle trajectories, while the SIMPLE algorithm is used to solve the k-ε equation for the flow field. According to the PSIC algorithm, the particle mass distribution in the gas phase flow field can be obtained by adding the particle's action on the airflow as a source into the gas phase equation after obtaining the particle group motion trajectory, and then solving the mass component transport equation simultaneously. The governing equation for the gas phase is k-ε equation for the particle mass fraction transport.

$$\frac{\partial(u_i \alpha_p)}{\partial x_i} = \frac{\partial}{\partial x_i}\left[(v + v_i)\frac{\partial \alpha_p}{\partial x_i}\right] + S_p$$

Type: α_p is the particle mass component; v is the dynamic viscosity, Pa s; v_i is turbulent viscosity coefficient, Pa s; S_P is the source phase of particle

action; u_i is the velocity component, m/s; x_i is the distance component, m.

The release and transport of dust particles are the result of the movement of suspended particles and transition particles. In the case of ignoring ground creep, the source phase of particles S_P,It is composed of suspended particle source phase and jump particle source phase.

$$S_P = S_{sus} + S_{sul}$$

Where S_{sus} can be expressed as:

$$S_{sus} = -\beta_{sus}\frac{\partial}{\partial x_i}[\alpha_p(1 - \alpha_p)U_R]$$

Where, U_R is the relative velocity between particles and airflow, m/s; β_{sus} is the source phase coefficient of suspension action, which is set as 0.05.

According to the gas-solid two-phase flow theory, U_R can be expressed as:

$$U_R = \frac{4\bar{d}}{3C_\tau} \cdot \frac{(\rho_P - \rho_u)}{\rho_u}g$$

Type; $\bar{d}$ is the particle dynamic diameter, m; ρ_P and ρ_u are particle and air density, kg/m^3; C_τ is the viscous resistance coefficient of the granular and airflow. The influence of particles on the pulsation of air flow is considered g is the gravitational acceleration, 9.8m/s^2.

Jump particle source phase S_{sul} can be expressed as:

$$S_{sul} = -\beta_{sul}\frac{\partial}{\partial x_i}[\alpha_p(1 - \alpha_p)U_R \cdot \chi]$$

Type: χ is the coefficient considering the stacking effect of saltation movement; β_{sus} is the source term coefficient of the jump action, which can be taken as 0.15.

And χ can be expressed as:

$$\chi = \frac{(u_\infty^{2+}u_{0\infty}^2)(u_\infty - u_{0\infty})}{u_\infty^3}$$

Type:u0x is the ground friction coefficient, m/s; Ux is the critical friction velocity of particles, and the starting wind speed of particles is taken as m/s.

The mass distribution of dust particles can be accurately obtained by analyzing the dispersion of dust particles in the open air. The increase of the incoming wind speed is positively correlated with the atmospheric carrying capacity. In addition, due to the good followability of suspended particles and the increase of the diffusion Angle of suspended particles, the motion trajectory of dust particles presents a higher and farther trajectory, and there is an obvious "Plume" phenomenon. [Liu YuFeng, et. al., 2006]

Initialization programming

When the dust online monitor is energized, the baud rate is adjusted to 9600 and the ESP8266 module is initialized. After that, the WiFi is initialized to detect whether the WiFi module exists in the default state. After a short delay, if it does not exist, the ESP8266 module is repeatedly initialized in the initialization mode and then the next step is continued. If it is detected that there is an attempt to

connect to the WiFi network, set the mobile phone hotspot open account as Dzd and password as 19960306 to connect with the network through the hotspot. If the account password is connected correctly and successfully, continue to connect to the WiFi network; Connect to the WiFi network after a short delay, set the pin as the output state and the pin as the input state after displaying the system state. Responsible for signal input and output directly transfer data. The initialization program flow chart is shown in figure 10.
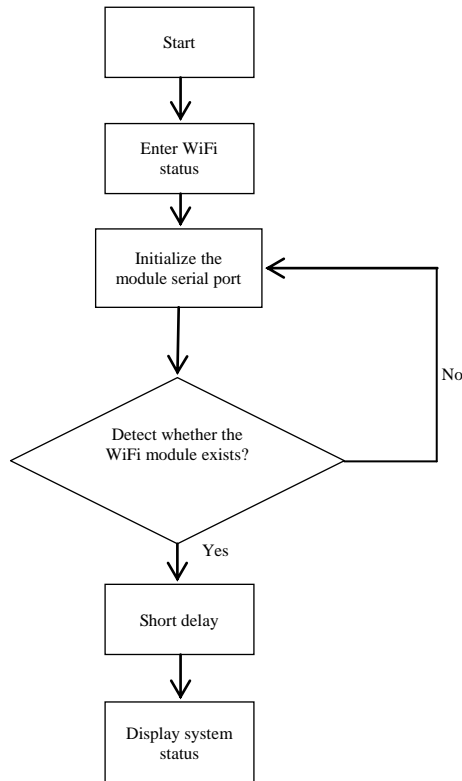

Fig. 10 Initialization program flow chart

Test program design

Dust monitoring instrument online of electricity, after finish the initialization has been performing PM2.5 test procedures, define the signal acquisition IO mouth (analog signal), will be sent to the display module display of PM2.5 data collected and set up the short time delay, then C program algorithm, dust will be collected to the concentration of the temporary array, and the setting density temporary array indices. Then, the volume decibel algorithm program of the noise sensor module is executed, and the volume decibel size IO port is defined. The detected sound size data is sent to the display module for display, and the sound algorithm is carried out through the C program. Db values temporarily stored array, and set db values temporarily stored array index. The detection of PM2.5 concentration and noise volume was completed in the dust noise detection program, and ESP8266 module was used to upload the collected data to the cloud platform and

receive the data from the cloud platform by connecting the mobile phone hotspots. The flow chart of the detection program is shown in figure 11.
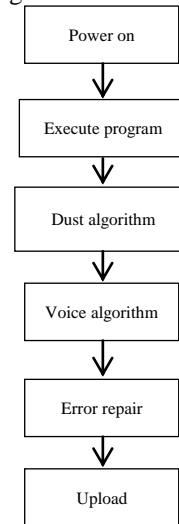

Fig. 11 flow chart of detection program

Display programming

After sensors to PM2.5 and noise data in the algorithm input ATMEGA328P_32LQFP SCM, SCM collect sensor input voice db and PM2.5 data collected, and then will collect the voice of the db, PM2.5 data into electronic signal input ATMEGA328P_32LQFP microcontroller, through OLED12864 LCD output in the form of Chinese characters, Numbers, letters, through the ESP 2866 module and mobile hotspot connection form to send data to the cloud platform, to create a TCP connection, The URL that generates the WEB request reads the server response and forwards it to the serial port. The collected data will be presented in the layout of pictures and Numbers in the established cloud platform, so as to analyze and summarize the data. The correct data will be presented in two templates (PM2.5 and sound decibel), which will be presented in the form of line graph for better comparison and planning.
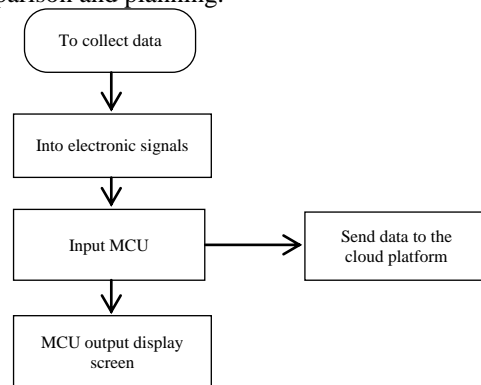

Fig. 12 shows the program flow chart

Cloud platform construction

Arduino program design:

(1) change thing_name to its own Arduino board name. This name must be the same as the name entered on dweet.IO;

(2) change the WiFi hotspot information to its own value.

Dweet website Settings:

(1) input the following url in the browser to view the latest 5 sets of monitoring data:

https://dweet.io/get/latest/dweet/for/my-thing-name

(2) input the following url in the browser to view all monitoring data:

https://dweet.io/get/dweets/for/my-thing-name

(3) replace my-thing-name with my own Arduino Uno board name.

Freeboard. IO Settings:

(1) create an account;

(2) create a new board;

(3) add datasource;

(4) add a pane.

SYSTEM DEBUGGING AND RESULTS

Debugging steps

Debugging is divided into three steps: the first step is hardware debugging, the second step is software debugging, the third step is cloud platform debugging, and the fourth step is system operation debugging.

The first step is to check whether the circuit of the online dust monitor is well connected, and then check whether the components of all modules are intact one by one, then check whether each module can normally realize the corresponding functions, and finally check the overall appearance of the online dust monitor, check whether the circuit board is damaged and whether the connected circuit is solid.

The second step is to use the detection function in the Arduino IDE of the development software to detect whether the program is wrong, to verify whether the logic of the program is correct, and if the error is found, we need to modify the statement with error in the program.

The third step is to turn on the hotspot, download the program to Arduino Uno R3 and start running the program. The Arduino sends a set of monitoring data to the dweet. IO server every five seconds. Open the web page and observe whether the data saved on the dweet. IO server is correct. Open freeboard. IO virtual instrument webpage, and observe whether the display of detection data is correct.

Step 4 software use Arduino IDE download the complete program to the Arduino microcontroller, put all the modules of the whole hardware system, software part and hardware part, the combination of the complete form a monitoring instrument online of dust, the use of mobile phones on hot spots, dust, according to data from the monitor screen can have online and make noise, smoke blown to the sensor trigger sensors. Open the page of freeboard. IO virtual instrument and observe whether the data and display of each part are correct.

Debugging results

(1) hardware debugging results: each module can realize functions normally, circuit boards are intact, and connected circuits are firm.

(2) software debugging results: all programs are detected in the development software Arduino IDE, and the development software Arduino IDE does not report an error and displays normally.

(3) cloud platform debugging result, website normal receiving data, and the dust on-line detector display module display data synchronization (there will be a delay of 5 s), numerical and line chart will fluctuates with the change of the environment, fluctuate dust online detector display module display of data and normal received data have a short delay, but not affect the normal operation dust on-line detector, and data display and upload.

Fig. 13 cloud platform display diagram

CONCLUSION

With the development of science, signals such as noise and dust are sent by network, which can realize remote monitoring. The application of this scheme to the supervision of construction sites will improve the management efficiency and supervision level. The implementation of the program will enable the construction unit to go to a higher level of management, strengthen government supervision, timely grasp the site details. The online dust monitor takes Arduino as the core and constructs the whole system composed of detection, display, communication and other modules. The detection module consists of PM2.5 detection module and sound detection module. The PM2.5 detection module USES sharp optical dust sensor (GP2Y1014AU0F) to detect PM2.5 concentration in the air. The sound detection module adopts the high-sensitivity microphone sensor module (ky-037); Display module adopts OLED LCD screen to display PM2.5 concentration and sound decibel value; The communication module USES lesin WiFi module (ESP8266) to transmit local data to the cloud platform. Cloud platform USES freeboard website to receive data and display. The design realizes the online monitoring of dust and noise pollution in construction site and improves the management level. Quantitative data can be used to reflect the degree of dust pollution in construction site. It contributes to environmental governance, and will become a powerful tool for the construction of scientific environmental protection sites.

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