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DESIGN OF DUST MONITORING SYSTEM FOR PRODUCTION WORKSHOP

MingMao Gong*, SiZhe Zheng, SiYan Xu
School of Electronic Information Engineering, Sichuan Technology and Business University, Chengdu 611745, China.
Corresponding Author: MingMao Gong, Email: fengxu0217@126.com

Abstract: As an important place for clean production, real-time monitoring of dust concentration in production workshops is the key to ensuring product quality. Starting from practical application requirements, this article designs a dust monitoring system for production workshops based on STM32. The system integrates PG-03CR six channel laser dust sensor and SHT85 digital temperature and humidity sensor, and combines TFT screen to achieve information visualization and real-time warning function. In addition, through 4G wireless communication technology combined with MQTT communication protocol, monitoring data is transmitted in real-time to the monitoring center, achieving remote monitoring functionality. Through actual testing and comparison verification, the system has maintained good response accuracy and error control in PM2.5, PM10, and temperature and humidity monitoring.
Keywords: Dust monitoring; STM32; Laser dust sensor; 4G; MQTT protocol

1 INTRODUCTION

Dust adhering to the surface of products can affect product quality, such as in industries such as electronics, food, and pharmaceuticals, leading to an increase in defect rates. Employees who are exposed to high concentrations of dust for a long time may also face the risk of occupational diseases such as pneumoconiosis, respiratory diseases, and skin diseases. Dust monitoring can help companies understand the dust situation in the workshop, take effective protective measures, improve product yield, and reduce the risk of employee illness [1-2]. With the development of Internet of Things technology, dust online monitoring systems based on Internet of Things technology can gradually collect real-time concentrations of particulate matter such as PM2.5 and PM10, as well as environmental parameters such as temperature and humidity, and upload data to cloud platforms through 4G communication modules to achieve remote monitoring and intelligent alarm reporting[3].

2 DESIGN SCHEME FOR DUST MONITORING SYSTEM

The overall architecture of the system includes battery power management, sensor data acquisition, battery voltage detection, display module, and user interaction. The system is powered by a 7.4V lithium battery and is supplied with stable power through LDO to ensure that all modules operate at normal voltage. In the design of the dust monitoring system, the million level clean PG03CR dust sensor was selected, which has a particle detection range of 0.3~10um and can detect 6 particle sizes including 0.3, 0.5, 1.0, 3.0, 5.0, and 10um. The STM32F103 is chosen as the embedded microcontroller, which has powerful functions and low power consumption, meeting the overall control and low-power requirements of the system[4]. In addition, SH85 is used to detect temperature and humidity, and monitoring data is transmitted through a 4G wireless communication module. A 10.1-inch serial touch screen is used as the human-machine interaction interface. The overall system design diagram is shown in Figure 1.

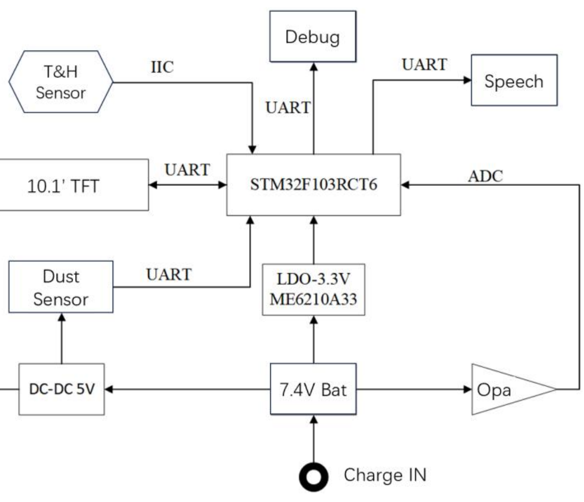

Figure 1 Overall System Block Diagram

3 HARDWARE CIRCUIT DESIGN

3.1 Voltage Stabilization Circuit Design

In this design, a 7.4V lithium battery is used for power supply, but both the TFT LCD screen and dust sensor require a 5V voltage, STM32, The working voltage of temperature sensors is 3.3V, so this system uses two voltage reduction circuits.
The 5V voltage regulator circuit is shown in Figure 2. The input terminal of LM29150RS-5.0 is connected to the main power supply section VIN, and the front end is connected in series with C16 and C17 filtering capacitors to suppress high-frequency interference and ripple voltage. The output terminal is connected to C18 and C19 to construct a complete input-output filtering network, further improving the system's anti-interference ability. The chip has an output capability of up to 1.5A, which is sufficient to meet the power supply requirements of stable and consistent brightness of TFT screens, ensuring the reliability and response speed of image display[5].

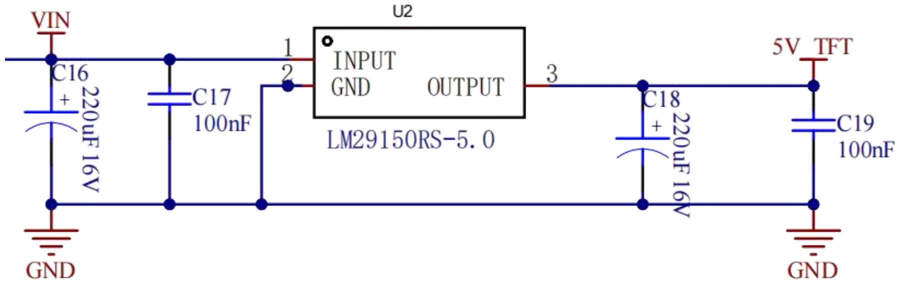

Figure 2 Schematic Diagram of 5V Voltage Regulator Circuit

The core control modules such as STM32F103RCT6 microcontroller and SHT85 temperature and humidity sensor require stable 3.3V voltage supply and are sensitive to voltage fluctuations. Therefore, the system design adopts the ME6210A33PG linear voltage regulator chip, which outputs a 3.3V voltage after voltage reduction and stabilization of the battery voltage[6]. The ME6210 chip has low static power consumption and fast response characteristics, suitable for power drive applications of embedded system main control chips. The circuit diagram is shown in Figure 3.

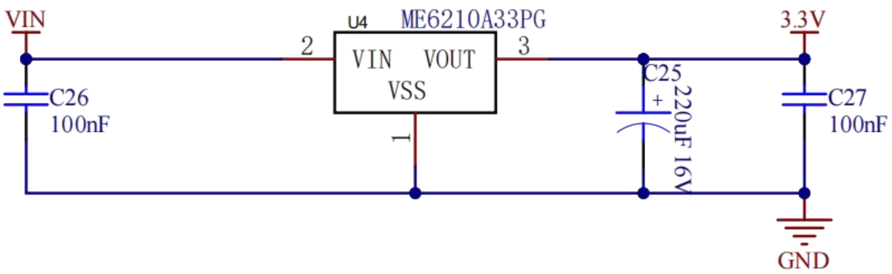

Figure 3 Schematic Diagram of 3.3V Voltage Regulator Circuit

3.2 Temperature and Humidity Module Design

This design uses the SHT85 temperature and humidity sensor module to monitor the temperature and humidity in the working environment in real time, ensuring that the dust monitoring system can compensate according to environmental conditions[7]. SHT85 has the characteristics of high precision and low power consumption, and is widely used in industrial environments. The sensor exchanges data with the STM32F103RCT6 microcontroller through the I2C communication protocol. The I2C bus communication simplifies the hardware connection, and its circuit schematic is shown in Figure 4.

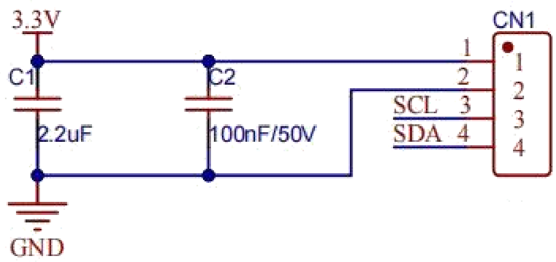

Figure 4 SHT85 Temperature and Humidity Sensor Circuit Diagram

3.3 Design of Dust Particle Module

This design uses the PG-03CR six channel dust sensor, which has six channel laser detection capabilities and can simultaneously output data on the quantity and mass concentration of particles with particle sizes of 0.3 μ m, 0.5 μ m, 1.0 μ m, 2.5 μ m, 5.0 μ m, and 10 μ m[8]. It is suitable for scenarios that require high air cleanliness. The PG-03CR sensor is based on the principle of laser scattering for particle recognition. It integrates a fan air pump, laser, photodiode array, and signal processing circuit internally. During the air sampling process, real-time recognition of particles of different sizes is achieved through the detection of scattered light intensity. The sensor has completed the calibration of particulate matter mass concentration at the factory, and defaults to outputting key parameter values such as PM2.5 and PM10. The relevant parameters are shown in Table 1. The sensor experiment uses UART interface for communication, and the circuit is relatively simple, so it will not be repeated here.

Table 1 PG-03CR Parameter Table

Parameter Category	Specific indicators
Detecting particle size range	0.3 μ m~10 μ m (six channels)
Particle size channel	0.3μm, 0.5μm, 1.0μm, 2.5μm, 5.0μm, 10μm
Detection accuracy (PM2.5)	0100μg/m³: ±10μg/m³, 1001000μg/m³: ±10%
Concentration resolution	1μg/m³
Output data refresh interval	1 second
working voltage	DC 5V ±0.2V
Working current	≤100mA
communication model	UART serial communication
response time	1 second
Working temperature/humidity	-10℃50℃; 095% RH
Cleanliness level standard	Compliant with ISO14644-1, ISO5 to ISO9 levels

3.4 Screen Display Module Design

The 10.1-inch TFT serial port screen is used as a display module to visually display key information such as the system's working status, dust concentration, temperature and humidity data. The display module interacts with the microcontroller through UART communication protocol to ensure fast data transmission and real-time updates. The serial port screen adopts the common TFT LCD display technology, which has high resolution and brightness, and can display clearly in various environments. The serial port screen is connected to the UART interface of the microcontroller through a dedicated adapter board. The adapter board also integrates SD card interface, buzzer interface, and speaker interface for users to update the serial port screen interface, which can easily achieve voice broadcasting and alarm functions. The actual picture of the screen connection is shown in Figure 5.

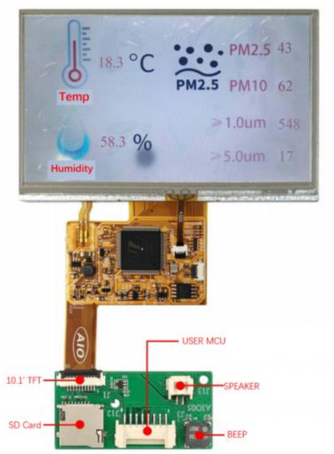

Figure 5 Screen Connection Physical Image

3.5 Design of Level Conversion Circuit in 2.5 4G Communication Circuit

This design uses the ML305 4G communication module for monitoring data transmission, and the hardware communication interface between this module and STM32 is UART interface. However, since the ML305 core operates at 1.8V, while the STM32 operates at 3.3V, the key point of this design lies in the level conversion circuit of the communication interface. The UART interface uses a full duplex communication interface, so level conversion only requires unidirectional conversion. The circuit schematic of this function is shown in Figure 6.
Taking the example of 4G sending data to STM32 in the upper left corner of the figure, when 4G-DTU_TX does not send data, transistor Q3 is turned off, and U3RX remains high under the action of the pull-up resistor, while UART remains idle; When 4G-DTU_TX sends data, the DTU_TX pin is 0V, and transistor Q3 is turned on. The U3RX pin is pulled low to a low level, and the serial port receives a low level. Through this simple circuit, the conversion process from 1.8V to 3.3V level is achieved.

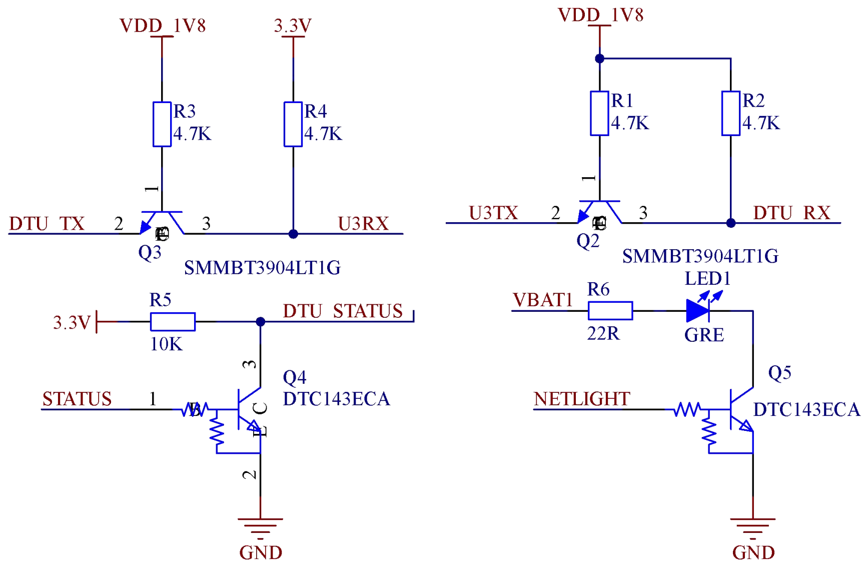

Figure 6 Design of Level Conversion Circuit in 4G Communication Circuit

4 SYSTEM SOFTWARE DESIGN

The dust monitoring system in the production workshop mainly monitors dust data through a six channel dust sensor, which uses UART interface to exchange data with STM32; Use the SHT85 temperature and humidity sensor to collect environmental temperature and humidity information, and display the relevant information on a 10 inch serial port LCD screen; At the same time, relevant data will be transmitted to the cloud platform through 4G modules to achieve remote monitoring functionality. The data collected by the sensor will be transmitted to the main program for processing and analysis, followed by data filtering to remove possible noise and interference. Then, the data will be corrected based on the characteristics of the sensor to ensure its accuracy. To ensure data stability, the main program calculates the average value, reduces the impact of sudden fluctuations, and detects the presence of abnormal data points. All collected data will be displayed in real-time on the TFT screen, and users can interact and view different data items through touch screens or buttons. When the data exceeds the preset security threshold, the system will trigger an alarm mechanism, display warning information on the screen, and remind through voice broadcast to ensure timely response. Even if the data exceeds the threshold, the system will continue to process and store the data to maintain continuous monitoring and recording. The software flowchart is shown in Figure 7.

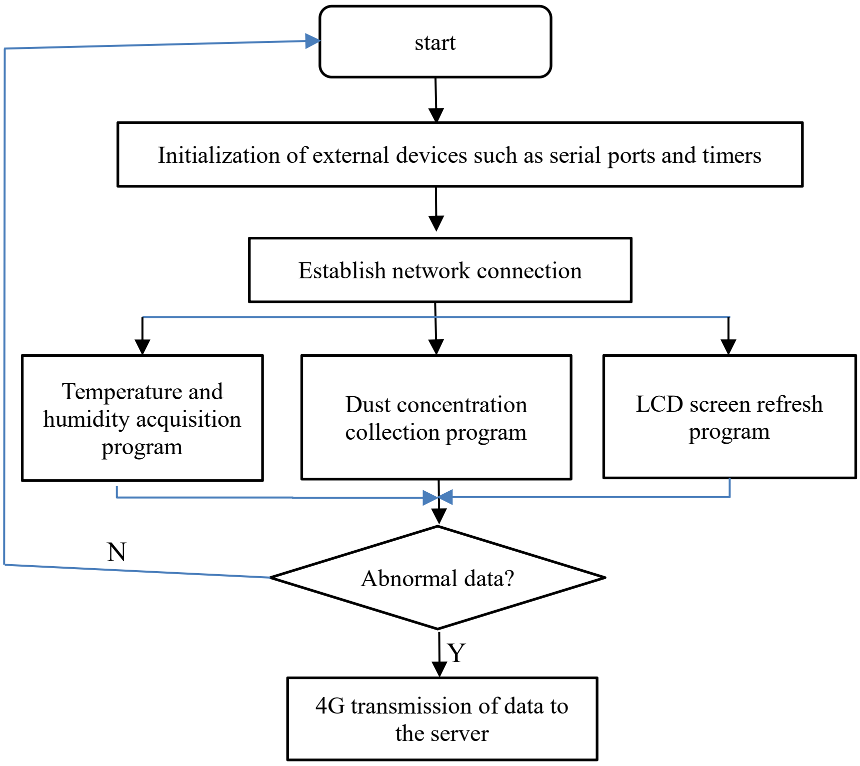

Figure 7 Overall Flowchart of System Software

4.1 System Testing and Result Analysis

During the testing process, the system selects a conventional laboratory environment as the testing site and conducts fixed-point timed sampling at five equidistant time points throughout the day, 9:00, 12:00, 15:00, 18:00, and 21:00, to observe the diurnal trend of temperature and humidity changes. After each collection, the system transmits data to the PC through the serial port for recording, and compares it with the data from the standard temperature and humidity meter to provide a reference value for calculating the measurement error of the system.

Table 2 Temperature and Humidity Test Results

time	Measure temperature (℃)	Actual temperature (℃)	Absolute error (℃)	Relative error (%)	Measure humidity (%)	Actual humidity (%)	Absolute error (%)	Relative error (%)
9:00	17.8	17.6	0.2	1.14	59.3	57.5	1.8	3.14
12:00	22.6	22.5	0.1	0.44	51.2	49.5	1.7	3.44
15:00	21.3	21.2	0.1	0.47	52.4	51.5	0.9	1.75
18:00	18.5	18.3	0.2	1.09	54.2	54.5	0.3	0.55
21:00	16.3	16.2	0.1	0.62	57.8	57.5	0.3	0.52

As shown in Table 2, the measurement error of the temperature and humidity sensor exhibits certain fluctuations at different time periods. The absolute error between the measured temperature and the actual temperature is within 0.2 ℃, and the relative error is between 0.44% and 1.14%. The temperature error varies at different time periods, with a significant error of 0.2 ℃ at 9:00 and 18:00, and relative errors of 1.14% and 1.09%. The absolute error of humidity measurement error is generally small, ranging from 0.3% to 1.8%, and the relative error range is 0.52% to 3.44%. Overall, the error between the measurement results of the sensor and the actual values does not exceed a reasonable range, which can meet the needs of daily applications.

The dust test results are shown in Table 3. The PM2.5 and PM10 concentrations measured by the system in this design are close to the values of the standard dust tester at all five time points throughout the day. The maximum absolute error of PM2.5 measurement is 3 μ g/m ³, and the relative error is between 2.5% and 7.14%; The maximum absolute error of PM10 is 3 μ g/m ³, and the relative error remains between 1.47% and 5.10%, with the error controlled within an acceptable range. Overall, the PG-03CR sensor has stable output performance and high data reliability under this system structure, making it suitable for environmental scenarios such as dust-free workshops that require high particle concentration monitoring.

Table 3 Dust Test Results

time	Measure PM2.5 (μ g/m ³)	Actual PM2.5 (μ g/m ³)	Absolute error (μ g/m ³)	Relative error (%)	Measure PM10 (μ g/m ³)	Actual PM10 (μ g/m ³)	Absolute error (μ g/m ³)	Relative error (%)
9:00	38	37	1	2.70	62	60	2	3.33
12:00	43	40	3	7.14	69	68	1	1.47
15:00	40	38	2	5.26	64	63	1	1.59
18:00	38	36	2	5.56	63	60	3	5.10
21:00	36	34	2	5.88	60	58	2	3.45

5 CONCLUSION

This design focuses on monitoring dust in production workshops, covering the entire process from hardware collection to data processing, presentation, and communication. Advanced sensors have been selected for data acquisition in hardware to ensure the accuracy and effectiveness of the data. The data processing module verifies, filters, and analyzes the collected environmental data, improving the accuracy and reliability of the system. The system also integrates a 4G wireless communication module, which can transmit real-time monitoring data from the production workshop to the IoT platform, achieving data visualization and remote monitoring functions.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Lina Zheng, Zikang Feng, Jia Liu, et al. Cross-concentration calibration of low-cost sensors for effective dust monitoring at construction sites. Journal of Aerosol Science. 2024, 182, 106456.
[2] Parkavi A, Sowmya B J, Sini Anna Alex, et al. Air quality and dust level monitoring systems in hospitals using IoT. Discover Internet of Things. 2025, 5(1): 23-23.
[3] Cody Wolfe, Emanuele Cauda, Milan Yekich, et al. Real-Time Dust Monitoring in Occupational Environments: A Case Study on Using Low-Cost Dust Monitors for Enhanced Data Collection and Analysis. Mining, Metallurgy & Exploration. 2024, 41(4): 1709-1718.
[4] Santa Nestor, Sarver Emily. Advancing respirable coal mine dust source apportionment: a preliminary laboratory exploration of optical microscopy as a novel monitoring tool. International Journal of Coal Science & Technology, 2024, 11(1).
[5] Tuchman Donald P, Mischler Steven E, Cauda Emanuele G, et al. Equivalency of PDM3700 and PDM3600 Dust Monitors. Mining, Metallurgy & Exploration, 2024, 41(2): 719-725.
[6] di Vacri M L, Scorza S, French A, et al. Evaluation of SNOLAB background mitigation procedures through the use of an ICP-MS based dust monitoring methodology. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 2023, 1056. DOI: https://doi.org/10.1016/j.nima.2023.168700.
[7] Karcz Stanisław, Skrabalak Grzegorz, Brudnik Andrzej, et al. Dust Particle Counter for Powder Bed Fusion Process. Sensors, 2022, 22(19): 7614-7614.
[8] Brajesh Kumar Kori, Himanshu Agrawal. Dust Monitoring Systems and Health Hazards in Coal Mining A Review. International Journal of Trend in Scientific Research and Development, 2021, 5(3): 172-177.