International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 13, Issue 11 [November. 2024] PP: 125-132

A medical respiratory detection system based on a gas-sensitive sensor

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ABSTRACT: *In modern society, with rapid economic growth and technological advances, there is an increasing demand for safe, efficient and intelligent systems. This trend is especially reflected in the monitoring and management of production and living environment. Traditional data collection and processing methods are often inadequate to meet the needs of modern society when faced with complex and large-scale scenarios. Therefore, the development of an intelligent system that can both improve work efficiency and reduce operating costs has become a priority.What this paper realizes is an innovative medical respiratory detection system based on gas sensor. This system uses 51 single chip microcomputer as the core control unit, combines many advanced detection technologies such as air quality sensor, carbon dioxide concentration sensor, DHT11 temperature and humidity sensor, and realizes real-time monitoring and intelligent analysis of key parameters in the environment. When the monitored parameters exceed the preset safety threshold, the system will automatically start the buzzer to alarm and timely remind the abnormal conditions of the environment. At the same time, all monitoring data can be visually displayed through the LCD screen, and the parameter setting can be adjusted through key operation, making the system operation more user-friendly. In addition, through serial communication technology, data can also be uploaded to the upper computer LABVIEW to achieve remote monitoring and analysis of data, further improving the application flexibility and practicality of the system.The medical respiratory detection system not only meets the social pursuit of intelligent and automated technology, but also shows great potential in improving the accuracy and timeliness of medical monitoring. By realizing continuous monitoring and real-time feedback of environmental quality, the system helps to improve the safety of the medical environment and provide a healthier and safer living and working environment for medical staff and patients. The development of this system not only promotes the progress of medical monitoring technology, but also provides a strong technical support for the sustainable and healthy development of society and economy.*

Date of Submission: 06-11-2024 Date of acceptance: 18-11-2024

I. INTRODUCTION

Traditional respiratory function testing methods often require specialized medical equipment and operators, which are not only costly, but also have certain limitations in practical applications, especially for patients with chronic diseases that require long-term monitoring. With the development of intelligent technology, the development of a medical respiratory detection system using high-sensitivity gas sensors can provide a simple, low-cost and efficient solution for the monitoring of respiratory diseases. This gas sensor-based system can monitor the concentration changes of specific gases in the air in real time, and indirectly assess the respiratory health of patients by analyzing the composition of exhaled gas [1].

With the development of intelligent technology, the demand for human and financial resources has gradually decreased, while efficiency and stability have been significantly improved. When carrying out daily tasks, such as data monitoring and anomaly detection, the intelligent system not only reduces the dependence on manpower, but also reduces the cost of long-term operation. This is an important development trend in many industries, especially in those areas that require high accuracy and continuity. With the introduction of intelligent devices, the traditional workflow is undergoing fundamental changes. In repetitive and continuous work, intelligent devices reduce dependence on human labor through preset logic and automatic operation. This not only improves work efficiency, but also reduces the possibility of human error. Intelligent IoT products, such as intelligent temperature monitoring system and intelligent epidemic prevention and disinfection system, are becoming an indispensable part of daily life. They make our life safer and more convenient by improving monitoring and response efficiency. The ultimate goal of intelligent systems is to improve the quality of life by reducing people's burden, improving safety and efficiency. In this process, intelligent technology constantly improves itself, creating more possibilities for human beings. The combination of intelligent perception model and computer processing thinking constitutes the core competitiveness of intelligent products. They can simulate and expand human cognitive ability, and provide new perspectives and methods for solving complex problems.

The aim of this study is to develop a medical respiratory detection system based on gas sensors. By integrating multiple gas sensors, such as sensors for monitoring air quality, sensors for detecting carbon dioxide concentration, and sensors for measuring temperature and humidity, the system can comprehensively and real-time monitor key parameters in the environment and provide accurate data support for medical professionals. The system not only improves the efficiency of diagnosis and treatment of respiratory diseases, but also helps to assess the effectiveness of disease management and treatment through continuous monitoring, providing patients with more personalized and efficient health management solutions.

This paper designs a portable medical breath detection system. The portable device has its own Android power port and USB interface, which can be connected to a computer or a socket. This paper completed the overall design of the medical breath detection system, mainly including the hardware and software of medical breath; The hardware part mainly includes power module, MCU module, LCD display module, upper computer module, gas sensor module and buzzer module. The software part mainly introduces the development environment of LABVIEW software, the main work flow of the system: air intake - data analysis - transfer to MCU - upper computer - display/alarm; The software and hardware debugging steps of medical breath detection are explained in detail.

II. OVERALL DESIGN

Integrated multi-sensor monitoring: The system should be able to integrate air quality sensors, carbon dioxide concentration sensors and temperature and humidity sensors and other sensors to achieve real-time monitoring of key parameters in the air. The selection of these sensors should take into account their accuracy, stability and response time to ensure the reliability of the monitoring data.

Real-time data processing and display: 51 microcontroller as the main control unit of the system is responsible for collecting sensor data and preliminary processing. The system should provide an intuitive data display program, through the LCD display to show the current air quality, carbon dioxide concentration and temperature and humidity data, so that users can easily access the environmental information.

Dynamic Threshold Setting and Alarm: The system needs to provide a mechanism that allows the user to set the safety thresholds of each environmental parameter through physical buttons. Once the monitoring data exceeds these thresholds, the system should automatically activate the buzzer alarm to prompt the user to take appropriate protective measures.

Parameter Adjustment Function: In addition to threshold setting, the system should also allow users to adjust other related parameters, such as alarm volume or display brightness, etc., through the keypad, in order to enhance the user experience and applicability of the system.

Data communication and remote monitoring: considering that users may need to monitor the environment quality remotely, the system should support data communication with the upper computer (such as LabVIEW environment) through the serial port to achieve remote upload and display of data. This function not only extends the application scenario of the system, but also provides convenience for data analysis and long-term trend observation.

In this paper, a medical respiratory detection system based on gas sensors is designed to optimize the workflow of temperature and humidity, air quality, and carbon dioxide monitoring through intelligent means. The system simulates the manual acquisition process through an advanced data acquisition circuit. This circuit utilizes a highly efficient hardware pin design to capture and transmit data quickly, which greatly improves the efficiency of data acquisition in the workflow. This high-speed acquisition mechanism ensures the real-time and accuracy of the data stream, laying a solid foundation for subsequent processing. Next, in the data processing section, the system carries out efficient logical processing through the main control unit. This unit is capable of processing data in multiple formats and converting them to a standard format for subsequent monitoring and analysis. This not only improves the efficiency of data processing, but also ensures the consistency and reliability of the data. In data monitoring, the system is able to display multiple data in real time, and monitor data anomalies through complex code logic judgment. The system also includes emergency processing and prompting circuits to improve the responsiveness to emergencies and ensure the stable operation and feedback performance of the whole intelligent system.

III. HARDWARE DESIGN

3.1 Main control circuits

The domestic STC series single-chip microcomputer is built based on 51 cores and provides up to 40 digital I/O pins, which facilitates complex logic control. The configuration of this single chip microcomputer is simple and clear, and it is easy for programmers to quickly master and implement logic function development. Considering factors such as system task driving, group oriented demand, stability, cost control and task realization difficulty, STC51 is selected as the main control chip of the system [2].

STC main control circuit is a miniature central processing unit (CPU) based on 52 cores, developed by

STC Company, and widely used in various embedded systems and intelligent devices. This single chip computer integrates the basic modules of the computer, such as memory unit, interrupt unit, communication interface and timer, so that it can realize complex logic control functions. The core of STC master control circuit is its highly integrated internal structure, which enables it to handle 8-bit data bus and has 512 bytes of RAM memory. In addition, it supports power-off storage and has 8K storage space.

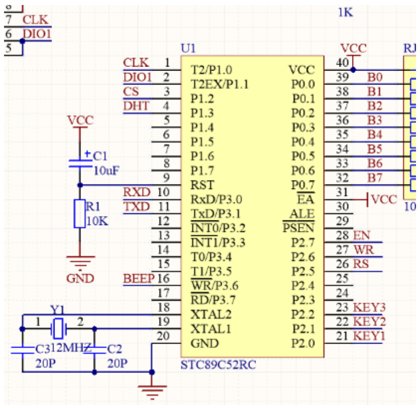

Fig. 1 Circuit diagram of the main control hardware

3.2 MQ air detection circuit

MQ gas sensor is a highly sensitive gas sensor. It can detect a variety of gases, including but not limited to hydrogen, sulfur dioxide and nitrogen. The key of this sensor is its sensitive material, usually a special metal oxide semiconductor, whose conductivity changes with the increase or decrease of specific gas concentration in the air. The core working principle is based on the chemical reaction between gas and metal oxide surface [3]. When target gas molecules contact the sensor surface, they will react at high temperature, thus changing the resistance of the material. The heating element inside the sensor maintains a constant temperature to ensure the chemical reaction.

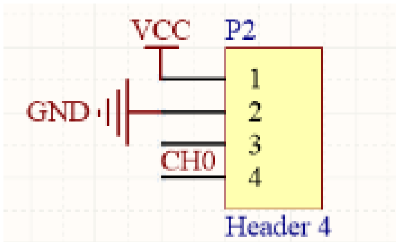

Fig. 2 Schematic diagram of MQ air acquisition circuit

CO and smoke concentration acquisition subprogram: MQ sensor can directly convert carbon dioxide concentration and air particle concentration into resistance value change, output analog voltage value [2] after signal conditioning, and then switch CH1 and CH0 pins through ADC0832 to convert analog quantity detected by sensor into digital signal and send it to MCU, which is finally displayed by LCD1602.

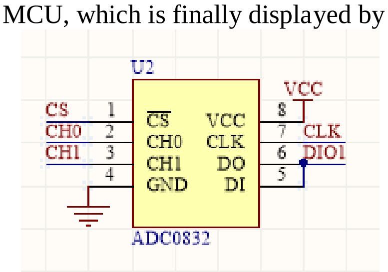

Fig. 3 ADC0832 Module

3.3 Data display circuits

The work of LCD display module is based on the characteristics of liquid crystal materials, that is, the change of liquid crystal molecular arrangement under the action of electric field can change the light transmittance. It enables LCD to display complex images in a low-power way. The LCD module can display a variety of data types, including text, images and graphics. Through fine pixel control, it can display simple English and Chinese characters to complex graphic design. LCD module supports multiple control modes. Serial and parallel control modes are common choices [4]. In serial mode, data is transmitted bit by bit through a single data line; In parallel mode, multiple data lines transmit data at the same time, which can improve the data transmission rate. The flexibility of these control modes brings more possibilities for system design. The control programming of LCD module is similar to computer control, which is relatively intuitive and easy to learn. It includes instruction setting, data reading and writing, operation control and other processes. This easy to program feature allows LCD modules to be quickly integrated into various electronic systems, as well as easy to maintain and upgrade.

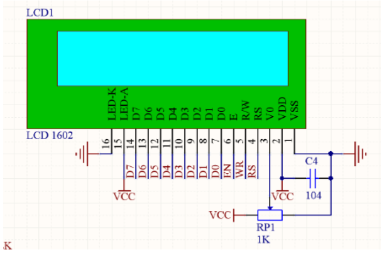

Fig. 4 Schematic diagram of the data display circuit

3.4 Temperature detection circuit

DHT11 circuit is an efficient temperature and humidity monitoring device, which achieves accurate environmental monitoring through unique design and technology. Its core lies in the integrated data calibration circuit, which can ensure the high accuracy of temperature and humidity readings. Compared with traditional environmental monitoring solutions, DHT11 provides more accurate data through its internal advanced calibration mechanism, which is crucial for application scenarios requiring fine environmental control.

One innovation of DHT11 is its single bus data transmission mode. This simplified transmission mode makes the communication between the circuit and processing units such as microcontroller more efficient and simple. The design of single bus interface not only reduces the number of required hardware connections, but also simplifies the overall system integration process [5]. DHT11 improves the accuracy of data by simplifying the process. It does not need additional detection circuits to process and convert data, thus reducing the possible errors in the link and improving the overall data acquisition efficiency. DHT11 is calibrated by software programming, which greatly increases its flexibility. Calibration through software code enables the equipment to adjust parameters according to specific application requirements, and these parameters can be stored in OTP registers for future adjustment and optimization.

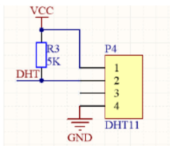

Fig. 5 Schematic diagram of the temperature and humidity circuit

IV. SOFTWARE DESIGN

4.1 System main program design

The gas sensor-based medical respiratory detection system is a highly intelligent work platform that integrates advanced technologies, and its core functions rely on a series of sophisticated peripheral circuits. These circuits ensure stable operation of the system through accurate data acquisition and processing, and perform critical tasks such as abnormality detection and alerting in real time. The system is unique in that it utilizes a variety of data acquisition modes, each designed to address the characteristics of different circuits. Choosing the most suitable data acquisition configuration is crucial to improve the performance of the whole system [6].

During the initial phase of the system, it is critical to accurately configure and initialize the environment for each peripheral circuit. This step takes into account the specific needs of each circuit, such as the configuration of pin functions, voltage and current settings, and so on. Correct initialization not only guarantees the correct operation of the system's later logic, but also provides the basis for effective error diagnosis and troubleshooting. In addition, the optimization of the overall performance of the system can not be separated from the efficient initialization in this stage. If the peripheral circuits are not successfully initialized, the subsequent data processing and detection functions may be blocked, thus affecting the operational efficiency of the whole system.

4.2 MQ monitoring subprogram design

The core component of the MQ module is an electrochemical sensor, whose surface is covered with a layer of specific chemicals. When the sensor is exposed to specific combustible gases, these gases react with the chemicals on the sensor surface, resulting in changes in conductivity. Inside, a well-designed circuit converts the change of conductivity into the change of voltage signal. In this conversion process, the circuit will amplify the tiny conductivity change so that it can be detected by conventional voltage measuring equipment [7]. As combustible gas will consume oxygen when burning in air, the decrease of oxygen concentration may indirectly indicate the increase of combustible gas content. Through pins, the microcontroller can read the output of the module and further process data.

4.3 Data display subroutine design

LCD data display is achieved by precisely controlling different pins. This control mode is based on binary data transmission, involving the use of specific pins, which are responsible for transmitting binary 0 and 1.

LCD operation process can be divided into three main stages: initialization, command sending and data processing. The initialization phase is the starting point of the whole process, which lays the foundation for subsequent operations. At this stage, the LCD performs self detection and preparation to ensure the correct processing of subsequent data and instructions. Next is the command sending stage. At this time, the controller sends specific operation commands to the LCD, which determine how to process and display data. The last is the data processing stage, in which the data is transmitted to the LCD through fixed data pins and displayed on the screen. Pins are used not only to select data or commands, but also to read or write operations, and to control the direction and number of data streams. These multifunctional pins ensure accurate data transmission and processing.

The specific process of LCD display is first the screen clearing operation, which clears all the old content on the screen to prepare for the display of new data. Next, initialize the built-in counter and pointer, which provides a reference for accurate data display. Then, the step of setting the pointer display position ensures that the data is presented correctly on the screen. Finally, the data processing stage includes data reception, storage, and display in a specific area of the screen. In this process, the gradual adjustment of the display pointer is crucial to ensure that the data can be displayed completely and accurately on the screen.

4.4 Temperature and humidity acquisition subroutine design

First, it is very important to configure the data pin of the DHT11 sensor as the output mode. This step ensures that the microcontroller can send the necessary start signal to the sensor. In the program, this is usually achieved by setting specific GPIO (General Purpose Input/Output) pins. After initialization, the pin outputs a low level signal. The duration of this signal is at least 18 milliseconds to ensure that DHT11 can accurately detect the start request of the microcontroller. This detail is critical to the success of subsequent communications. After sending the low level signal, the pin needs to output a short high level signal, which usually lasts between 20 and 40 microseconds. This high level signal tells the DHT11 sensor that the microcontroller is ready to receive data. Then, the pin is set to the input mode, and the microcontroller enters the waiting state to receive the response from DHT11. DHT11 responds by sending a specific signal mode on the data line. Once the response of DHT11 is detected, the microcontroller will start to read the 40 bit data sent by the sensor. These data include integer and decimal parts of humidity and temperature, and a checksum used to verify data integrity. After reading data, data verification is a non negligible step. This step ensures that the received data has no errors during transmission. The checksum is usually calculated by adding all bytes of humidity and temperature data, and then comparing with the checksum sent by the sensor. Once the data verification is completed, the subprogram ends and control returns to the main program. This marks the end of a complete data reading and verification process.

4.5 Program design for acquiring LABVIEW serial port

Using VISA serial device accessor to obtain data is an efficient and flexible method, which covers the whole process from configuring serial port to reading and writing data. First, users need to use VISA in LabVIEW to set specific parameters of the serial port, such as serial number and baud rate, to ensure that these settings match the target device. Then, open the designated serial port through the VISA Open function, which is a key step in establishing communication. The data reading and sending are completed through the VISA Read and VISA Write functions respectively, allowing users to process data in different formats. During data exchange, the VISA Status function can be used to monitor the serial port status, including detecting possible errors. After completing the data exchange, be sure to use the VISA Close function to close the serial port to free resources and ensure the status of the serial port when it is next used.

4.6 Programming of LABVIEW front and rear boards

First, the background VI (Virtual Instrument) is developed in the integrated development environment of LabVIEW. As the core processing and storage unit of data, this VI is responsible for receiving and processing signals from gas sensors. To establish the data connection channel between the foreground and background VI, the key to this step is to ensure that the data collected from the gas sensor can be seamlessly transmitted to the foreground interface for further analysis and display. On the foreground VI interface of LabVIEW, insert appropriate display controls, such as charts, indicator lights or numerical display, as required. These controls will be used to display breathing detection data in real time, including key parameters such as air quality, carbon dioxide concentration, temperature and humidity. After all configurations are completed, run VI. At this time, you can observe that the controls on the foreground interface begin to reflect the real-time data processed from the background VI. In this way, users can visually see the current respiratory environment quality and any possible abnormalities.

V. EXPERIMENRAL VALIDATION

5.1 System software testing

The primary task of software debugging is to ensure the accurate acquisition, efficient transmission and effective processing of data. In this paper, a set of unique encapsulated subroutines is designed, which should not only be executed in strict accordance with the provisions of the requirements analysis, but also be able to run independently to reduce the dependence between the software. In this process, special attention was paid to two aspects: first, the standardization of input data and the controllability of internal logic, and second, the standardization of output data format to ensure its smooth use in downstream tasks and secondary development. In addition, the system's emergency handling capability and the rationality of the functional logic were also emphasized. Through the integration test of subroutines, not only the rationality of the main program execution process is verified, but also the overall robustness of the system is enhanced. After the software is uploaded to the hardware, the task logic of the system can run smoothly according to the set process. In order to improve the transparency of system operation and facilitate real-time monitoring, a human-computer interface is introduced. The prompts on the real-time monitoring interface can ensure the correctness of the software operation logic and make timely adjustments. In the debugging process, special attention is paid to the testing of the system pin function. The correct configuration and use of the pin function is essential to ensure the overall performance of the system. Through accurate pin function mapping and regular function testing, it is ensured that each pin can work as expected, thus optimizing the performance and stability of the whole system.

The data line of the temperature and humidity sensor was connected to the wrong GPIO port during the integration and debugging of hardware and software of the first device. The data reading fails or is unstable. Finally, I checked each connection in detail to ensure that the pin and data line of each sensor were correctly connected to the corresponding port of 51 MCU. The code cannot be compiled successfully due to incorrect programming syntax or missing library file. When the system is running, the data displayed on the LCD is incomplete or misplaced. Check the data manual of the LCD to confirm the correct wiring and initialization procedures. Add a delay or adjust the data refresh frequency in the code to ensure stable data display.

5.2 Overall system testing

Joint commissioning of hardware and software is a critical step in ensuring the overall performance and reliability of the system. First, the co-commissioning process begins with ensuring the accuracy of the physical connections of the hardware components, such as the processor, sensor, and actuator interface pins, as well as the software logic, which is the basis for the overall system interaction.

The focus is on testing the functionality of individual modules (e.g., sensors, communication interfaces, etc.) to ensure that they respond as expected. This includes not only testing the physical performance of the hardware, but also verifying the accuracy of the software code to the operation of the hardware. This is followed by debugging of the emergency handling functions. This involves simulating various anomalies and observing how the hardware and software respond together. Any unintended behavior needs to be located through the software error message, and combined with the hardware status for accurate error detection.

In addition, iteration is inevitable during debugging. Each iteration is an opportunity to identify and deal with the bugs found in the system. At the same time, data processing optimization is a continuous task in the whole debugging process. According to the data acquisition characteristics of hardware and the processing capacity of software, optimize the real-time monitoring and processing of data to reduce the data gap period in logic execution. Finally, in order to enhance the user's interactive experience, intuitive code prompts can be added. This not only helps users better understand the system status, but also is an important part of improving the system availability and friendliness.

Fig. 6 System power-up test

The system can automatically buzzer alarm after detecting the abnormality. The test is successful as shown in the figure below.

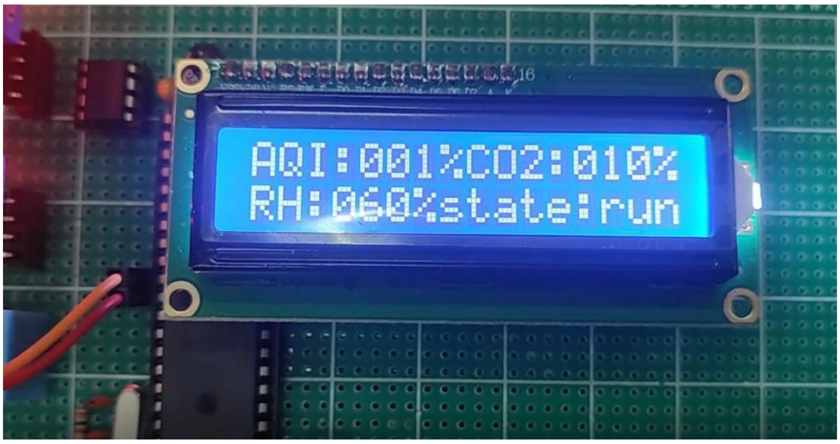

Fig. 7 Anomaly Acquisition Test

The upper computer of the system monitors in real time, and the test is successful as shown in the figure below.

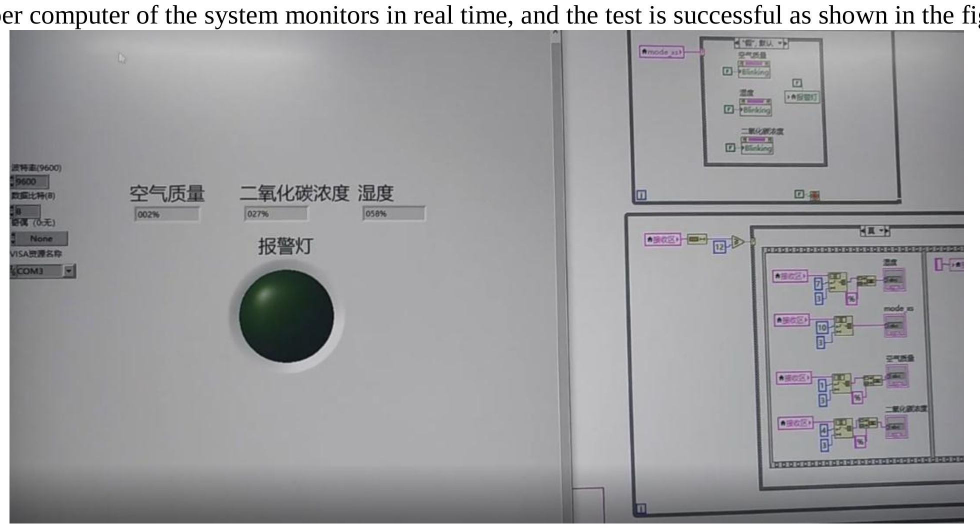

Fig. 8 Upper computer monitoring test

VI. CONCLUSION

In the context of today's advancing technology, intelligent systems have become a hot topic in research and industry. The aim of the project is to design a medical respiratory detection system based on gas sensors, which automates the process through a series of well-designed detection and processing circuits, and greatly reduces the consumption of manpower and material resources in the traditional way of working. The core concept of the system is its efficient resource management and optimized workflow.

In this paper, we designed a portable human-machine interactive device for medical respiratory detection system, through the key human debugging health thresholds, human debugging health respiratory thresholds according to the environmental conditions and thus more accurately detect the human respiratory health and health of the gas environment, through the host computer is more intuitive and more convenient to detect air quality. And family and friends can remotely monitor the patient's health status.

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