Design and Implementation of Smart Wardrobe Hardware based on STM32

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Abstract

This paper mainly studied the effective plan of the intelligent wardrobe. Dehumidification and mildew prevention: when the humidity sensor detects the humidity in the environment outside the range; automatically control the dehumidifier working. Intelligent lifting: When it is inconvenient to take, adjust the height of the clothes above by the button on the mobile phone or the closet. Intelligent sensor light: when the environment of taking clothes is dark; automatically control LEDs to turn on. Disinfection and sterilization: The wardrobe is regularly sterilized with high temperature or ultraviolet rays,to change the traditional single function of traditional wardrobes that can only store clothes, so that people can have a more convenient lifestyle.The core of the hardware is the development board of the STM32 series. Its detection principle and data transmission run through.Its data acquisition layer uses median filtering, dual ADC sampling, and multi-sensor data fusion technology.

Keywords

STM32F103; Smart wardrobe; Temperature and Humidity Sensor; Dual ADC Sampling.

1. Introduction

Smart wardrobe is one of the many branches of smart home.It is a smart product with traditional functions such as basic storage, as well as new functions such as intelligent voice, disinfection, heat preservation and dehumidification [1]. Considering the reason of cost and other factors; most of the current smart wardrobes are based on existing wardrobes with sensors, microprocessors, and external devices. Through the transformation and design of the traditional wardrobe to achieve the purpose of intelligent wardrobe.

At present, the intelligentization of domestic smart wardrobes is mainly focused on intelligent lifting: allowing the upper layer of the wardrobe to automatically rise and fall according to sensor detection [2]; moisture and dehumidification[3]: drying clothes regularly; disinfection and sterilization: regular high temperature or ultraviolet disinfection and sterilization of the wardrobe Automatic lighting: In the dark environment, the wardrobe can automatically turn on several aspects.

In addition to most of the functions mentioned above, the intelligence of the smart wardrobe has also been demonstrated in other aspects. Panasonic of Japan has developed a smart wardrobe—Laundroid [4] with automatic stacking. In addition, there are smart wardrobes that can implement functions such as virtual fitting and recommendation of dressing. Hundreds of smart wardrobe industry are presented, standards are extremely different.

2. Overall designed scheme of smart wardrobe hardware based on STM32

The smart wardrobe of this text is composed of STM32F103 development board, temperature and humidity sensor, photoresistor sensor, smoke concentration sensor, drying and dehumidification, LED lights and other peripherals. It is built around three main functional modules: dehumidification and drying, automatic lighting and fire warning. The overall diagram of the hardware system of the intelligent wardrobe to be designed is shown in figure 1:

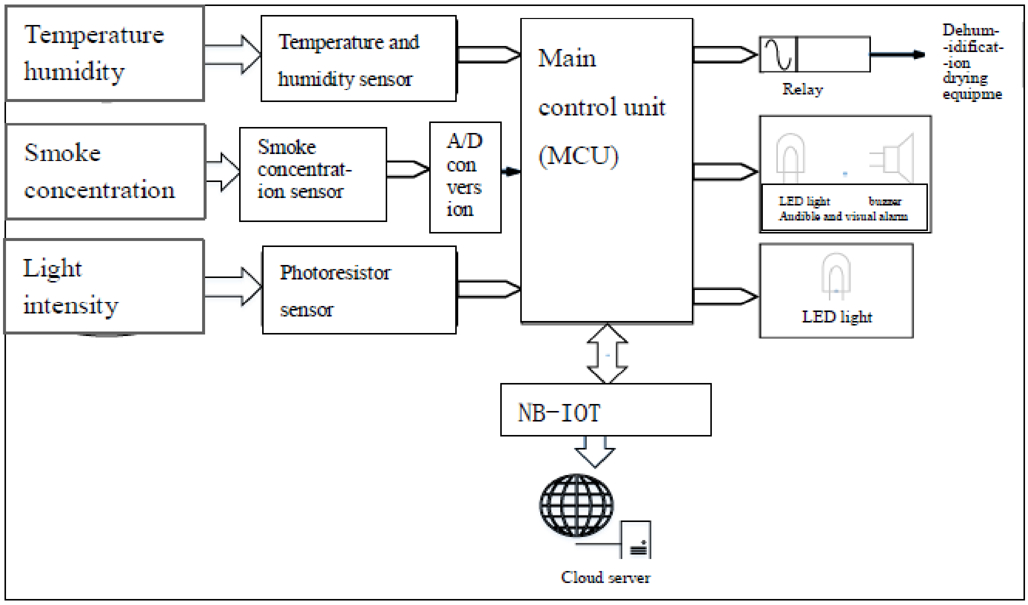

Fig.1. Overall structure of the system

3. Detailed hardware design scheme based on STM32 smart wardrobe

3.1 Development board of STM32F103

The reason for choosing STM32 series single-chip microcomputers is that compared with the traditional 51-series single-chip microcomputers, the advantages and disadvantages of the two currently popular single-chip microcomputers are shown in Table 1:

Tab.1 Comparison of STM32 and C51 microcontrollers

	MCU digits	Working frequency	ROM	RAM	Address space	Peripheral interface
STM32	32bit	72MHZ	20K-1MB	128B-1K	64KB	less
89C51	8bit	2MHZ	2-64K	8-256K	4GB	more

Due to the superior performance of STM32,we finally chose the STM32F103 microprocessor of the STM32 series. The STM32F103ZET6 development board is a development board equipped with a STM32F103 microprocessor. The physical map of the development board is shown in figure 2:

Fig. 2. STM32F103ZET6 development board

In addition to the data in the table, the STM32F103ZET6 development board equipped with I2C, SPI, CAN and other communication interfaces, besides one SDIO port, one 12-bit synchronous ADC, 3 USART, 2 UART, 1 USB and 112 general-purpose I / O ports. At the same time, the STM32F103 also uses a nested vectored interrupt controller (NVIC), which posses 60 shieldable channels and supports 16 priority levels. At the same time, it also has an external bus (FSMC) to enable the code to run in off-chip memory. The overall framework of the chip is shown in figure 3:

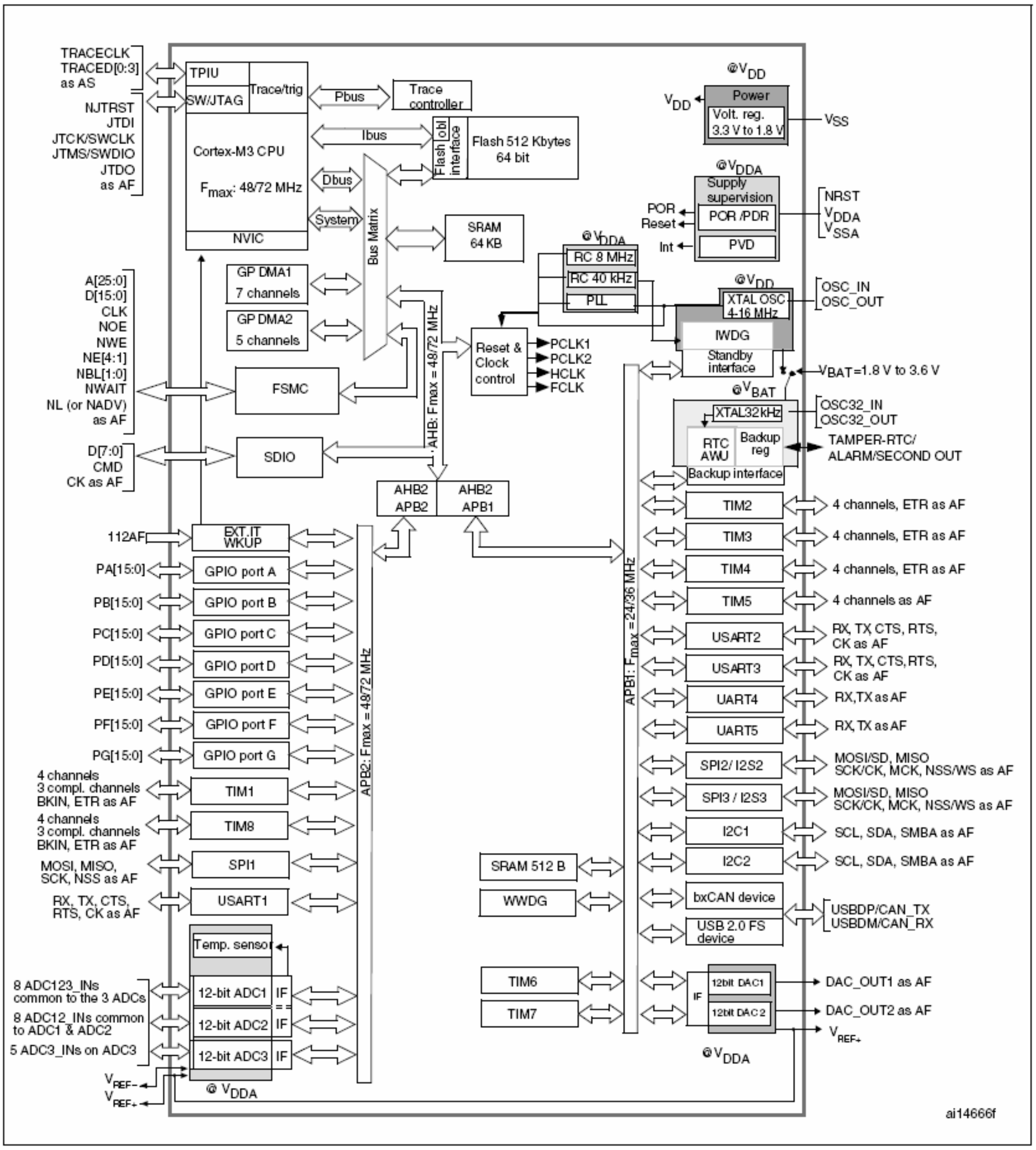

Fig.3. STM32 overall framework

3.2 Dehumidification and drying module design

3.2.1 Temperature and Humidity Sensor

Temperature and humidity sensor DHT11 is a built-in digital chip to complete the calibration function, and an integrated sensor that realizes the output signal as a digital signal [5]. DHT11 includes a resistive humidity sensing element and an NTC temperature measuring element. The humidity sensing element and temperature measuring element are connected to an 8-bit microcontrollers.

The DHT11 can measure the humidity range: 20% -95% RH. The measurement error in this humidity range is: ±5% RH, the measurable temperature range is: 0-50℃, and the error in this range is:±2℃.

The DHT11 sensor consisted of 3 pins, these are VCC, GND, and DATA respectively; the DATA pin is responsible for data sending and transmission.

The specific sensor structure and circuit diagram are shown in figure 4:

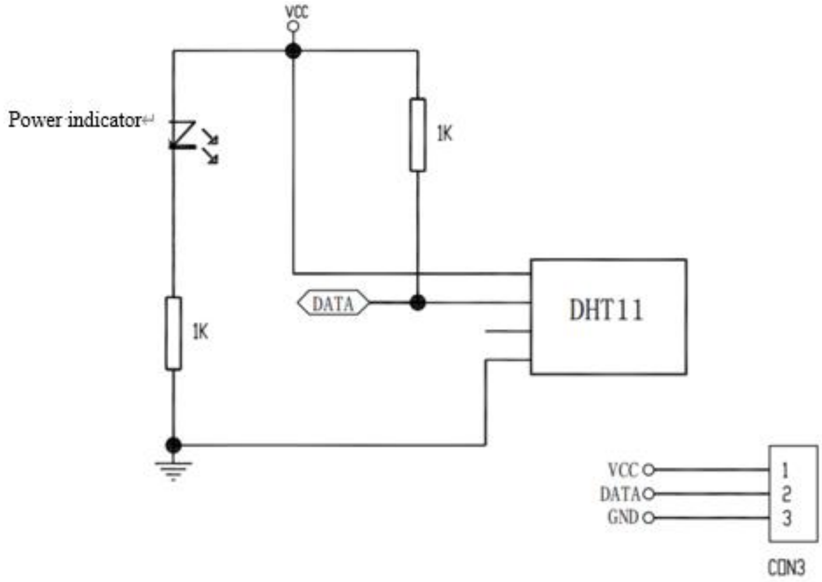

Fig. 4. DHT11 sensor circuit

The dehumidification and drying module is composed of DHT11 temperature and humidity sensor and dehumidification and drying equipment. The STM32 single-chip microcom puter serves as the central control of the entire module: it monitors the temperature and humidity data in the environment through the sensor; and then processes and judges the collected data to Determine whether the temperature and humidity data exceeds the set threshold; if it exceeds, start the dehumidification and drying equipment to decline the humidity in the environment. The specific structure of the module is shown in Figure5:

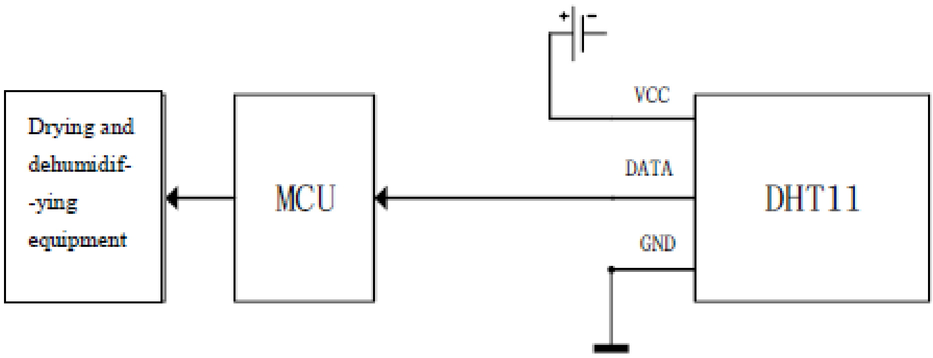

Fig. 5. Structural diagram of dehumidification and drying module

3.2.2 Temperature and Humidity Data Collection

The DHT11 sensor converts the collected real-time temperature and humidity data into a digital signal and transmits it to STC89C52. The sensors are connected using a unidirectional bus manner. In a single bus system, data exchange and control are performed by a single bus. Only one type of data can be exchanged at a time and can run two-way transmission. In DHT11,through sending a low-level acquisition signal of not less than 18ms to the DATA pin; then DHT11 responds, and then pulls up the resistance with a period of time; thereby obtaining the last measured temperature and humidity data stored in DHT11. The temperature and humidity data collection flowchart is as follows:

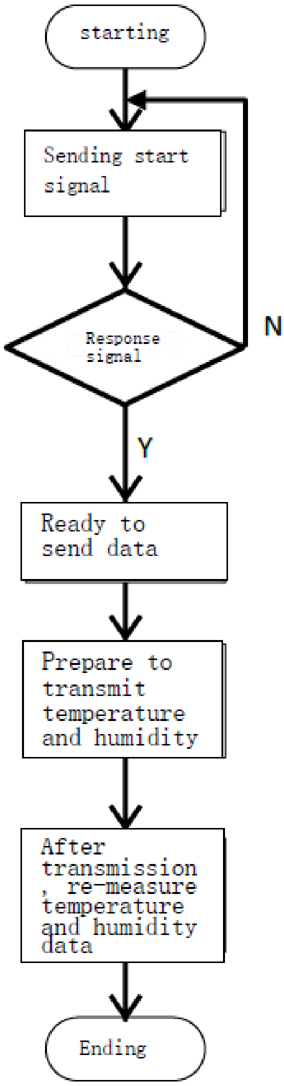

Fig. 6. The temperature and humidity data collection flowchart

3.3 Design of automatic lighting module

The smart closet, we use a light sensor of photoresistor type, which is suitable for light detection in daily home environments. The physical diagram of the photoresistor sensor is shown in Figure 7:

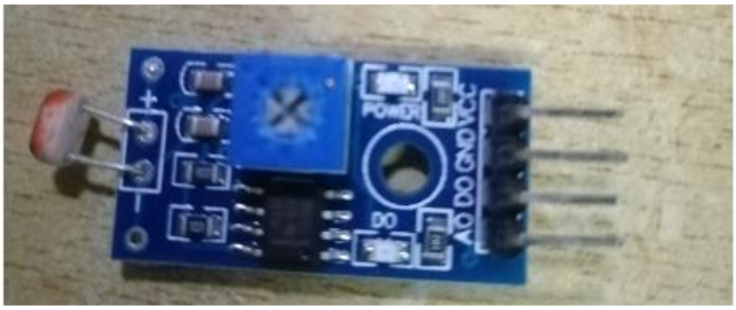

Fig. 7. Photoresistor sensor

The photoresistor uses the semiconductor characteristics to detect the intensity of light ,which will formulate hole electron pair and contribute changes when it encounters light [6]. When the incident light is stronger, the resistance of the photoresistor is smaller; the weaker, the larger the resistance. As long as our human eyes can feel the light, it will cause the variation of the photoresistor resistance.

There are two types of photoresistor sensors: three-wire and four-wire. We use a four-wire photoresistor here. The four-wire photoresistor has a total of four pins: VCC , GND, DO pin for output switching signal and AO pin for outputting analog signal. The sensor circuit diagram is shown in figure 8 below:

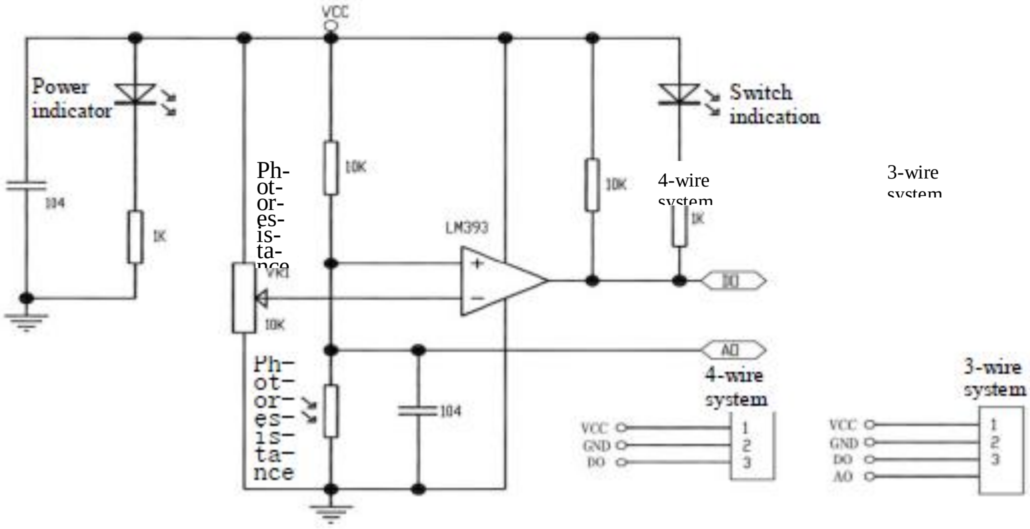

Fig. 8. The circuit diagram of photoresistor sensor

The automatic lighting module consisted of a photoresistor sensor, a LED light, and a single-chip microcomputer.The implementation principle: The single-chip microcomputer continuously detects the level signal output from the DO pin of the photoresistor sensor. When the low level detected that indicates that the surrounding light intensity is very weak , the single-chip computer controls and lights the LED light to supplement the lighting.The overall structure is similar to temperature and humidity sensor, except that the peripherals are replaced with LED lights, and the temperature and humidity sensor is replaced with a photoresistor sensor.

3.4 Design of Fire Warning Module

3.4.1 Smoke concentration sensor

The smoke sensor monitors the smoke concentration and flammable gas in the air; when the smoke concentration in the air reaches a preset smoke concentration threshold, it sends an alarm signal to notify the user to deal with it as soon as possible to prevent fire or get the purpose of resolving an emergency.

We use an MQ-2 gas sensor. The detection circuit of the sensor detects the smoke concentration in the environment through the MQ-2 gas sensor and outputs an analog signal. The gas-sensitive material used in the MQ-2 gas sensor is conductive in clean air Lower rate of tin dioxide (SnO2). In this way, when a flammable gas exists in the environment where the sensor is located, the conductivity of the sensor will increase as the concentration of the flammable gas in the air increases[7].

The MQ-2 gas sensor has a total of 4 pins, which are AOUT, VCC, GND, and DOUT pins respectively. The AOUT pin is the output terminal of the analog voltage signal. DOUT is a TTL high and low level output terminal, which is judged according to the smoke concentration threshold set by the adjustment potentiometer on the module, and outputs a high or low level. If we do not need to know the specific value of the smoke concentration, we only need to to obtain a certain level signal by DOUT pins. And when we need accurate smoke concentration value, we can get the voltage signal output from the AOUT pin; get a specific value after analog to digital conversion. The specific structure is shown in figure 9.

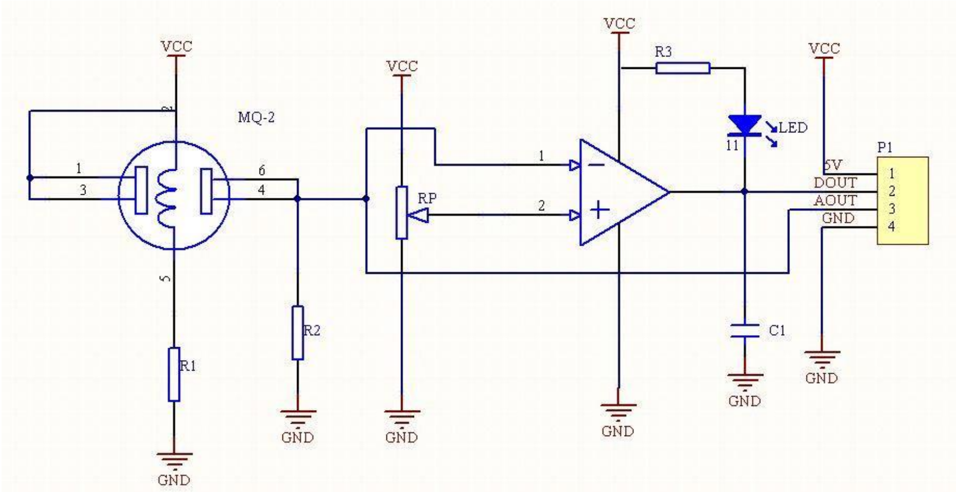

Fig. 9. MQ-2 smoke sensor circuit

(3) Connection diagram with STM32 microcontroller

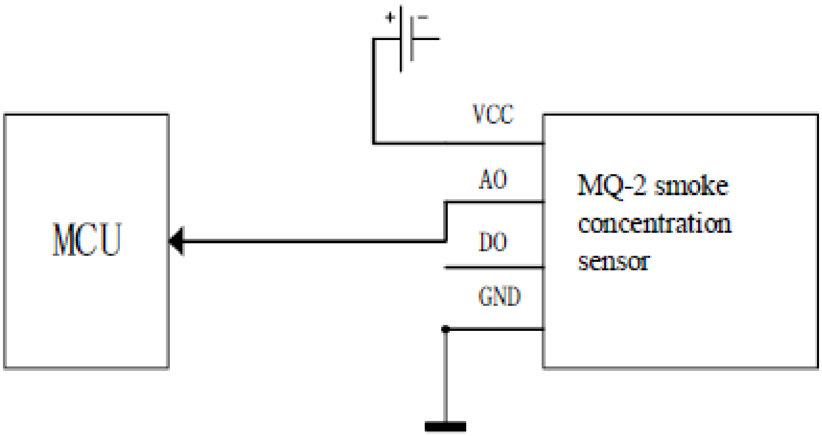

Fig. 10. MQ-2 and MCU connection diagram

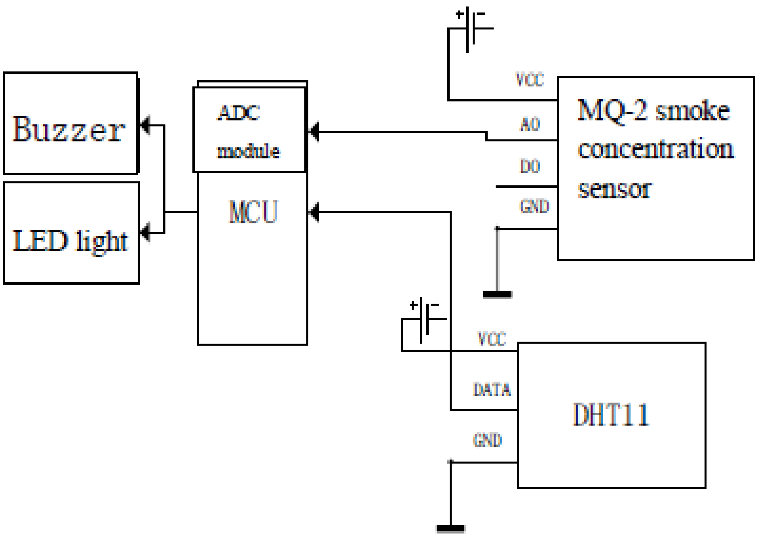

Fig.11. Structure diagram of fire warning module

The early fire warning module is composed of MQ-2 smoke concentration sensor, buzzer on STM32 board and LED2 device. First, the STM32 microcontroller will collect the smoke concentration on the smoke sensor. If the concentration is found to exceed the standard, it will continue to detect whether the temperature and humidity of the sensor module exceeds the threshold. If both exceed the specified threshold, the buzzer and LED2 lights will start to send out a warning. The structure of the module is shown in Figure 11:

3.4.2 Smoke concentration data collection

The smoke concentration data collected by the MQ-2 smoke sensor used in this system can be output in two forms,in which one is to output a switching signal directly through the DOUT pin. When the smoke concentration collected by the sensor is higher than that set by the potentiometer, the DOUT indicator on the sensor module is lighting on and the DOUT pin outputs a low level; when the smoke intensity is below the threshold, the DOUT pin outputs a high level. If we need to get the specific value of the smoke density, we need to get the analog signal output from the AOUT pin; get the specific value through A / D conversion.

The specific smoke collection process is shown in figure 11:

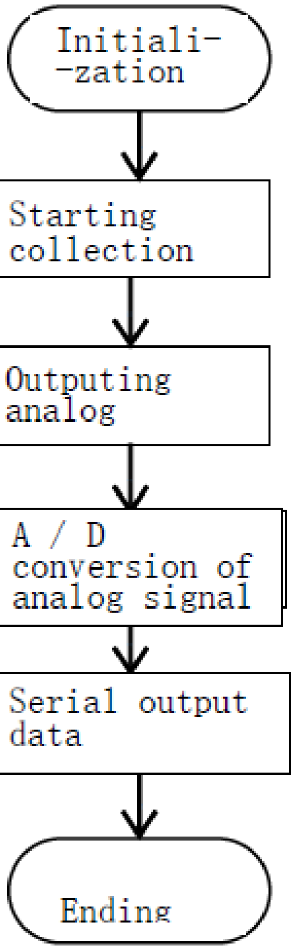

Fig.12. Smoke data collection flowchart

After the ADC completes the conversion and performs data transmission through DMA, we will get a 12-bit digital value. We can convert this number into an analog voltage through the formula for easiler observation: as shown in formula (1).

$$2\text{\textasciicircum}12/3.3 = X/Y \Rightarrow Y = (3.3X)/2\text{\textasciicircum}12 \quad (1)$$

Finally, we will output the 12-bit digital value and converted analog voltage output through the serial port.

3.5 Hardware integration

The hardwares of the entire functional module system is shown in Figure 12:

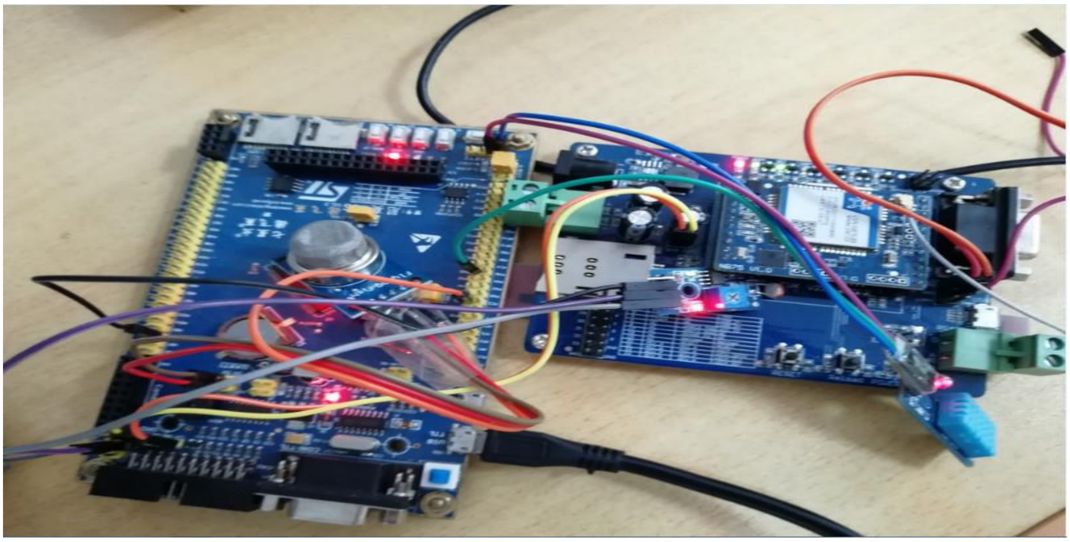

Fig. 13 Models of hardware

First, the sensor collects temperature, humidity, light intensity, and smoke concentration data, and then transmits the collected data to the main control unit. The temperature and humidity and light intensity data are directly transmitted to the main control unit.While the smoke concentration sensor is sampled by ADC. After the sampling is completed,running A/D conversion and then send the value of the A/D conversion to the serial port output to shown. After all data collection and processing operations are finished, the data is sent to the transmission module through the serial port, and sent to the cloud server through the AT instruction.

4. Software design scheme based on STM32 smart wardrobe

4.1 Data Processing Layer Design

In this system, the collected temperature and humidity data and smoke concentration data are mainly processed objects; the temperature and humidity data are processed using the median filtering algorithm. The smoke concentration data is sampled using multiple ADC.

4.2 Dual ADC Sampling

After we have collected the smoke concentration data, we need to perform A/D conversion. In the data collection, we used ADC1 for A / D conversion; but through the previous introduction, we can use two ADC converters to sample the smoke concentration data at the same time[8]. The advantage of doing like this is that the sampling rate of the smoke sensor is increased, which makes up for the shortcoming that the single ADC is not fast enough. Improved the accuracy of the smoke concentration data. The conversion results collected by the dual ADC are stored in the upper 16 bits of ADC1_DR and lower 16 bits of it.

4.3 Multi-sensor data fusion

Multi-sensor data fusion is used in the early fire warning module in this paper. Multi-sensor data fusion is to organize the data provided by multiple sensors in the system through some related form. This article mainly uses its detection / judgment fusion level, which fuses the detection data of two sensors, temperature and smoke concentration, to determine whether a fire has occurred.

The data fusion decision process based multiple sensor in this system is shown in figure 14:

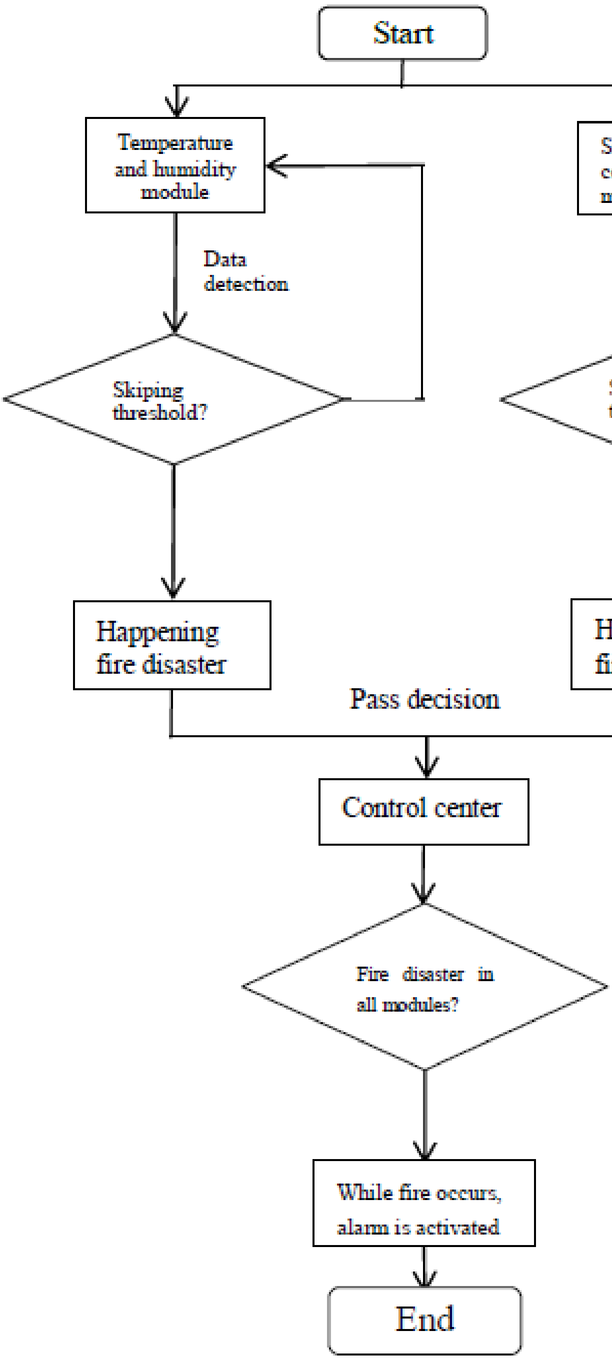

Fig.14. Fire module decision diagram

NB-IoT is a narrowband cellular communication technology highlighted by the 3GPP standards organization in September 2015, also known as narrowband Internet of Things (NB-IoT) technology [9]. NB-IoT technology has the characteristics of strong link, high coverage, low power consumption, and low cost. Specifically, compared with the existing wireless communication technology, NB-IoT can cover a wider area and has a stronger signal penetration ability .It can be used where ordinary 3, 4G signals are difficult to penetrate. And the cost will not be more expensive than the existing module, a communication technology with a very broad market and application prospects.

In this system, USR-NB75 uses a transmission module based on the NB-IoT network, which is used to connect the serial port to the server and network data transmission. The transmission module mainly transmits data to the server through the AT instruction, and sets the transmitted data and the target server through the AT instruction.

4.4 Software Integration

After the data collection and processing, we obtained the temperature and humidity data, smoke concentration data, and light intensity data of the sensors for environmental monitoring, thereby completing the operation of switching peripherals and data transmission. The control structure of the system is shown in figure 15:

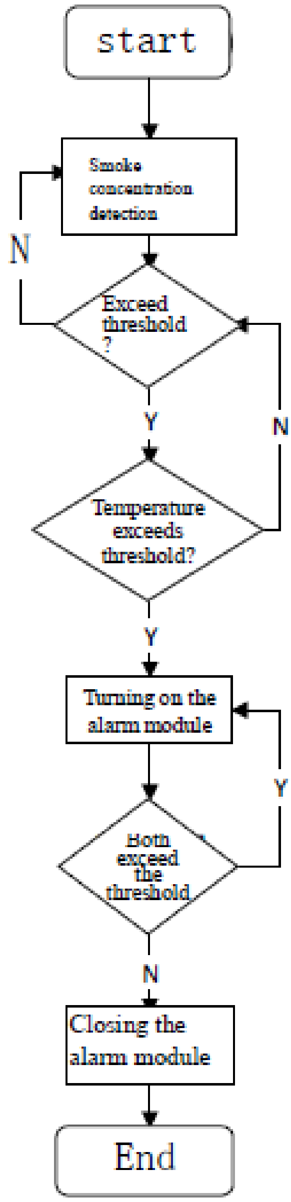

Fig.15. Software control flowchart

5. Summary

This paper discusses the hardware design and implementation program of a smart wardrobe with functions such as dehumidification and drying, automatic lighting, and fire alarm. It introduces used sensor and other technique from data collection, single-chip processing of data, and transmission module for data transmission,getting a complete resolution for the implementation of the functions given above, and getting idea for the combined use of sensors . The basic functions of smart wardrobes have been implemented. But due to time and technical issues, this article describes how to connect and expand smart wardrobes with other smart home products, including how to implement a self-organizing network of node networks between smart wardrobes. Implementing a complete and clear smart home network through networks such as wifi or ZigBee has not been deeply involved and considered.

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