Visualized Classroom Energy Saving Lighting System Based on Passive Detection

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Abstract

Abstract: In view of the current situation that the number of people in the classroom is small and the lighting area is large, and the number of classroom personnel cannot be accurately searched, this paper designed a passive detection of energy saving lighting system. The system takes STC12C5A60S2 as the core, proposes a method to detect the number of people by using two groups of infrared tubes separated by each other, and uses photosensitive resistance to detect the intensity of ambient light, so as to determine whether to turn on the light and the number of people according to the intensity of light and the number of personnel intrusion. The clock chip can be used to control the start and end time of the lighting system to avoid the management of classroom by classroom inspection; The system can measure the classroom temperature, and upload the temperature information and the flow information to the cloud platform, which is used for students to visually query the comfortable and idle self-study classroom and teachers to statistically check in. After testing, the system runs stably and achieves the purpose of intelligence, high efficiency and energy saving.

***Keywords**: STC12C5A60S2; E2PROM; Infrared antitube; DS1302; NBIoT; LCD1602 display.*

I. Introduction

In recent years, with the rapid development of communication, sensors, computers and other technologies, the lighting industry is also undergoing continuous innovation. In the present world advocate energy conservation and emissions reduction to ease the global greenhouse effect under the background, now a single way of lighting is no longer meet the needs of people, in real life, waste of energy is still very common, especially in many schools, there are lights normally on empty classroom, intelligent lighting control technology arises at the historic moment [1-7].

In recent years, more and more Chinese and foreign scholars have carried out in-depth research in the field of intelligent lighting control, and intelligent lighting schemes have emerged one after another. Intelligent lighting control technology can be traced back to intelligent lighting control equipment based on field Bus [8-9]. Yan Qiurong's team designed an intelligent lighting control system for universities based on wired network communication technology based on the combination of low-level networking and cloud interconnection [10]. Pan Youshun's team conducted distance measurement of WiFi sites through AP sites, and the single chip microcomputer transmitted the distance measurement results to the lighting management server in the management layer for real-time positioning processing through the communication layer, so as to realize intelligent remote control of the lighting equipment in the experimental building [11]. Although the above two studies have realized intelligent lighting in buildings, there is no in-depth study on lighting control in small areas. Using LoRa transmission and infrared induction technology, Tong Li's team proposed a lighting control method that can transmit control signals through the PC end using tree network structure [12]. Yan Zhankun's team from Zhejiang University developed an intelligent lighting control system based on ATMEL89C52 microcontroller, and realized the intelligent control of regional power supply by using infrared body sensing device [13].

The existing intelligent lighting equipment, most USES the pyroelectric infrared sensor human body [14-17],

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principle of pyroelectric infrared sensor technology is through the body temperature of 37 degrees to trigger the emission of infrared radiation induction, but unable to do as long as people in the state of the light would have been on, when the environment temperature is close to the body temperature of the reduced sensitivity, In addition, the infrared ray has a low ability to penetrate obstacles, which affects the user experience. It is not suitable for classroom lighting such a long time lighting scene. However, the signal location method [18-20] has poor anti-interference performance, and it is difficult to accurately determine the location in the case of slightly more people. In addition, the specifications of each classroom are different, so it is not universally practical. The method to determine the number and location of personnel through camera image processing is almost unavailable at night, and the cost is too high, the volume is too large, and the power consumption is also high, which will lead to more waste of resources. To this end, the system USES a number of statistical zoning control method, when detected intrusion classroom system open part of the lamps and lanterns, as the invasion of the increase in the number of lamps and lanterns of open quantity also will increase, when people reach a certain number, lamps and lanterns is all open, this method not only saves a lot of resources, but also can accurately detect the number of people, to achieve the real practical with energy saving.

II. The Overall Structure of the System and Its Basic Principles

The system uses low power consumption, strong anti-interference MCU STC12C5A60S2 as the main control system, automatic/manual mode Settings through the keys, in the manual mode: the system manually opens the light through the keys. Automatic mode: the first control level uses DS1302 clock module to determine the start and end time of the lighting system; The second control level uses photosensitive resistance to control the opening of the lamp according to the light intensity; The third control level uses two groups of infrared tubes in the same direction and separated from each other to detect the number of classroom intrintrators through the trigger logic of the front and back infrared tubes, and open the relative number of lights according to the number of intrintrators. The display part of the system is composed of LCD1602 liquid crystal, mainly display various data parameter information; Visualization application is realized by uploading the number of classroom personnel and temperature information to the cloud platform server using NBIoT, which is used for viewing empty classrooms and checking in. In the case of sudden power failure, the system realizes the power failure memory function by using E2PROM to store the set parameters. Finally, all position lights are switched on by relays. The overall structure of the system is shown in Figure 1.

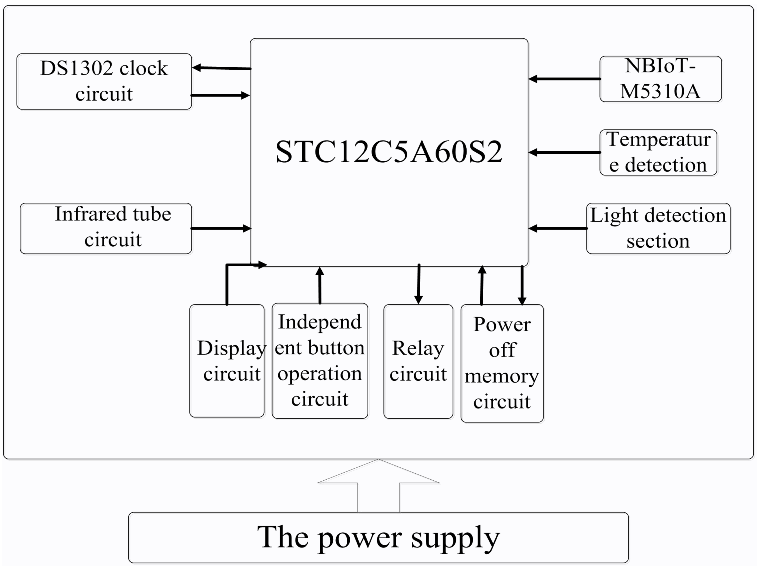

Figure 1 : Overall structure of the system

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III. System Hardware Design

3.1 Design of Intrusion Detection and Light Intensity Detection

Intrusion detection and light detection are mainly composed of two groups of infrared pairs of tubes in the same direction and parallel interval, one in front and one in back, and a photoresistor, two 104 potentiometers and two LM393 chips. The schematic diagram of the circuit is shown in Figure 3.

LM393 is a voltage comparator chip, its main principle is when the input voltage "V+>V-", the output high level, when the input voltage "V+<V-", the output low level.

In the circuit diagram, Q7 and Q8 are infrared receiving tubes, LED7 and LED8 are infrared transmitting tubes, R11 and R16 play the role of current limiting protection, and R12 and R17 are pull-up resistors of the receiving tube, in order to obtain high level. When there is an obstacle, the infrared light is reflected through the obstacle and received by the receiving tube, and the receiving tube is grounded. At this time, the voltage is "+" < "-", the OUT pin outputs the low level, and the LED indicator is on. Otherwise, the output level is high, and the LED indicator is off. The photoresistor VSR has the same principle as the infrared tube. When the light is stronger, the resistance value is smaller. "+" > "-", the OUT pin outputs high level, and the LED indicator is off. Conversely, output low level, LED light on. The sensitivity of both the infrared tube and the photoresistor can be adjusted according to different environmental requirements with a potentiometer of 104 specification.

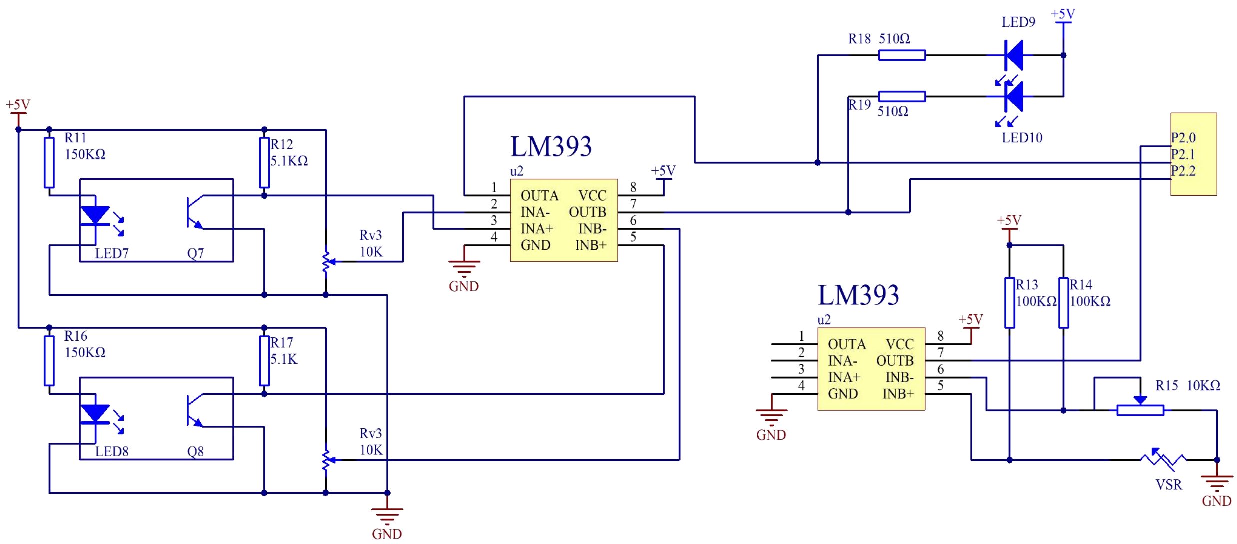

Figure 2: Schematic diagram of intrusion detection and optical intensity detection system

3.2 Clock Circuit Design

In order to turn on or off the lighting system within the specified time, DS1302 chip is used to set the start time of the lighting system, in which IO, SCLK, RST are connected with the MCU pin P2.3, P2.4, P25. By reading the time information sent from the clock chip, the user sets the parameters by pressing the button, which are processed by the MCU and displayed on the LCD screen. In order to prevent the time from stopping in the power-off state, a backup power supply is added to the chip. When the external power is turned off, the button battery will supply power to the clock chip immediately. The clock circuit design is shown in Figure 3, where R21, R22 and R23 are pull-up resistors, whose main function is to improve the anti-interference capability of the chip. The crystal

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frequency specified by the chip is 32.768kHz, which is responsible for providing the oscillation signal to the chip.

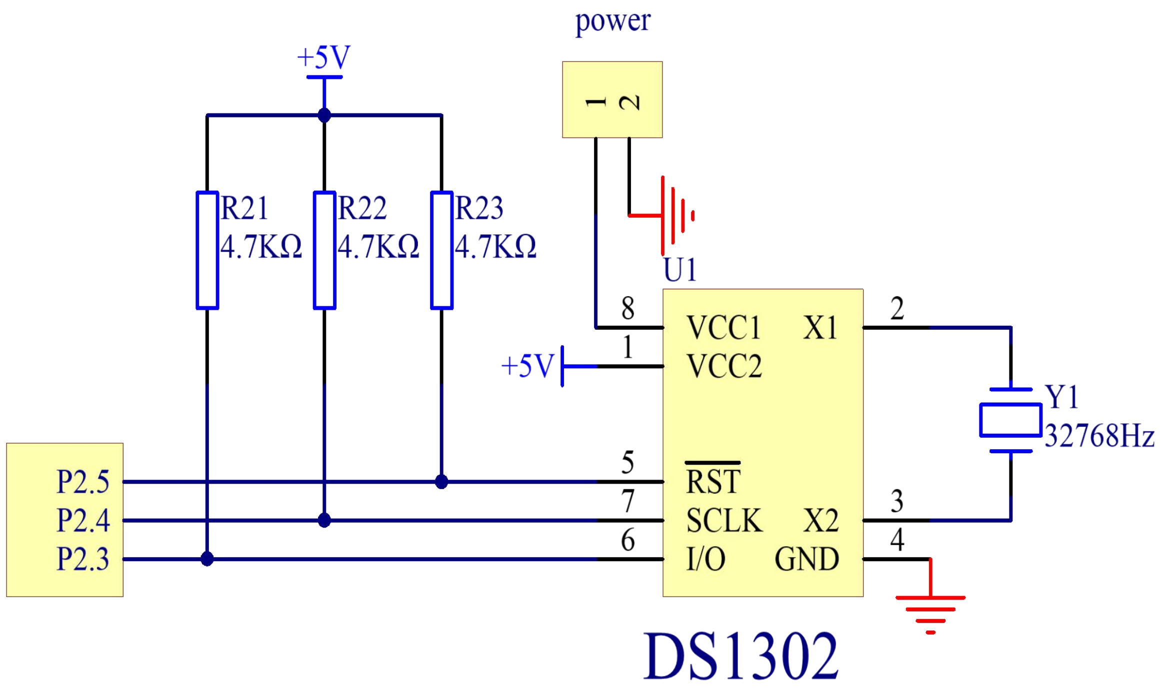

Figure 3: Schematic diagram of clock system hardware

3.3 Design of Relay Control Circuit

In order to make the single-chip microcomputer stably control the on-off of 220V AC voltage lamps with weak current, the classroom switch is replaced by a relay (circuit diagram is shown in Figure 4). This part is mainly composed of 38 decoder and six relays. After the control signal is processed by the microcontroller, the level signal sent by it can control on and off. The purpose of using 38 decoder is to save the number of pins. When the single-chip microcomputer input to the control instruction of 38 decoder, when the pin of the decoder is high, the transistor (NPN) turns on, the indicator lights up, the internal electromagnet access, the armature and the contact are attracted, KV turns on, that is, the switch is closed. When the MCU input low level, the transistor is not conductive, the electromagnet is disconnected, and the armature is separated from the contact by the internal shrapnel. KV is not conductive, that is, the switch is disconnected. When multiple relays need to be opened at the same time, the single chip microcomputer can scan one by one with the level signal at a high speed, and the system initialization state is the default low level off state.

3.4 Display Circuit Design

In order to intuitively display time, date, number of people, classroom temperature and other information, the system uses LCD1602 LIQUID crystal display screen in the display aspect, its working voltage is 4.5V-5V, working current is 2.0mA. It can display 16*2 characters at the same time, among which D0~D7 is 8-bit bidirectional data line; RS is the register selection pin, the data register is selected at high current, and the instruction register is selected at low current. R/W is read/write signal cable. Read operation is performed at high voltage and write operation is performed at low voltage. E terminal is the enabling terminal. When E terminal changes from high level to low level, the LCD module executes the command. Pin 3 and pin 15 can adjust contrast and brightness according to voltage and demand using a 103 potentiometer. (The circuit diagram is shown in FIG. 5)

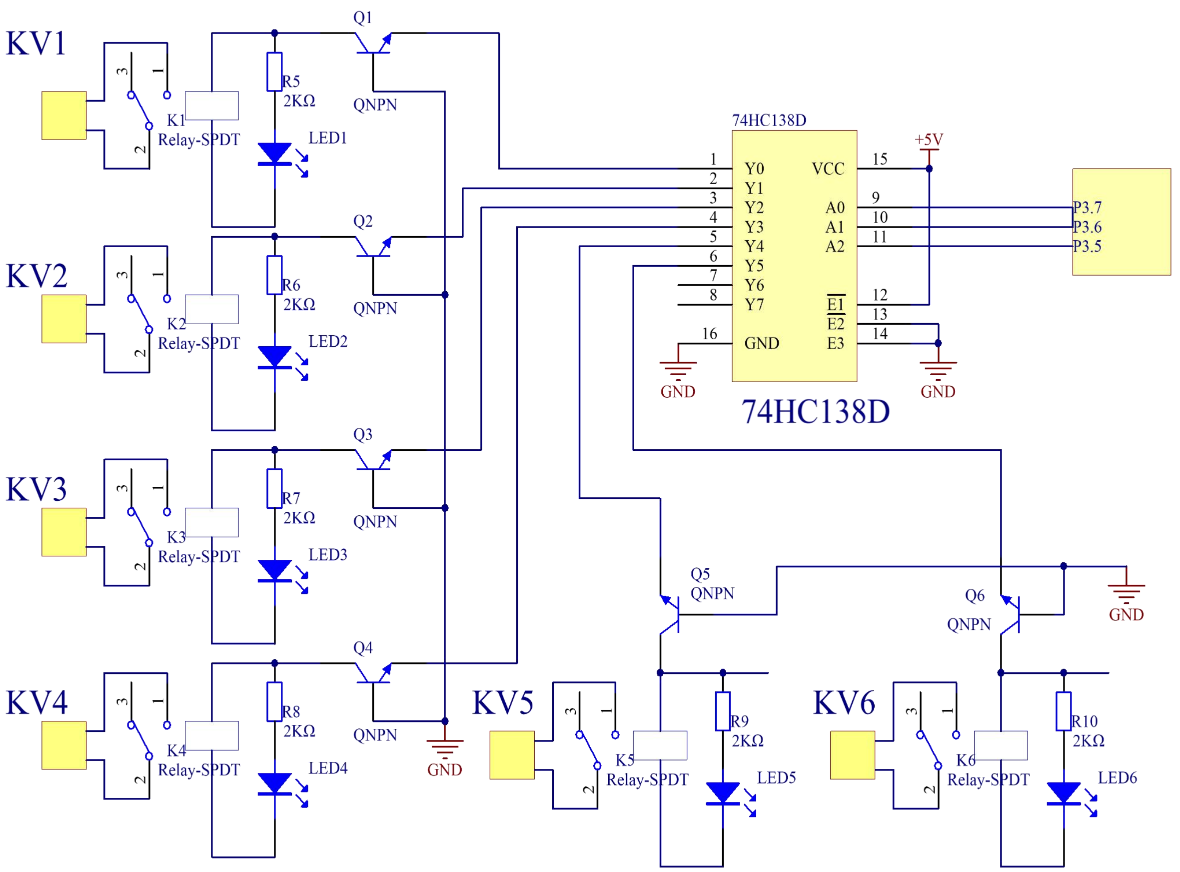

Figure 4 : Relay schematic diagram

3.5 Power Off Memory and Temperature Measuring Circuit Design

In order to guarantee the loss of different classroom parameter Settings, the system adds the memory function of power failure in the case of teaching building power failure. Power off memory chip uses 24C02 chip, storage capacity up to 2kB, the chip uses IIC bus protocol for communication, it has the characteristics of convenient interface, small volume, DATA power does not lose, in order to prevent clutter, or some pulse interference, circuit design, CLOCK connected to the MCU pin P1.0, DATA connected pin P1.1, A filter capacitor is added between Vcc and Wp to prevent interference.

In order to accurately obtain the classroom environment temperature, let students find a comfortable classroom, the system uses DS18B20 sensor to measure the temperature, the sensor through the single-line protocol communication, MCU read the data sent by the sensor and calculation, finally get the temperature value. In circuit design, the sensor data line is connected to the MCU pin P3.2, and a pull-up resistance is added between the data line and VCC to improve the anti-interference ability .

3.6 Communication Design of Nbiot Cloud Platform

The NBIoT module M5310A, which can communicate with China Mobile Onenet, is an industrial-grade module working in BAND3/BAND5/BAND8. The single chip microcomputer sends corresponding AT instructions to the module through serial port. LwM2M protocol is used to connect with China Mobile Onenet server to realize classification and uploading of multiple classrooms and various data streams. In this system, only the number of classrooms and temperature information are transmitted to realize cloud visual monitoring. The RXD on the module is connected with the T2XD pin P1.3 of single chip microcomputer, so that the single chip microcomputer can send instructions to M5310A and realize one-way serial communication.

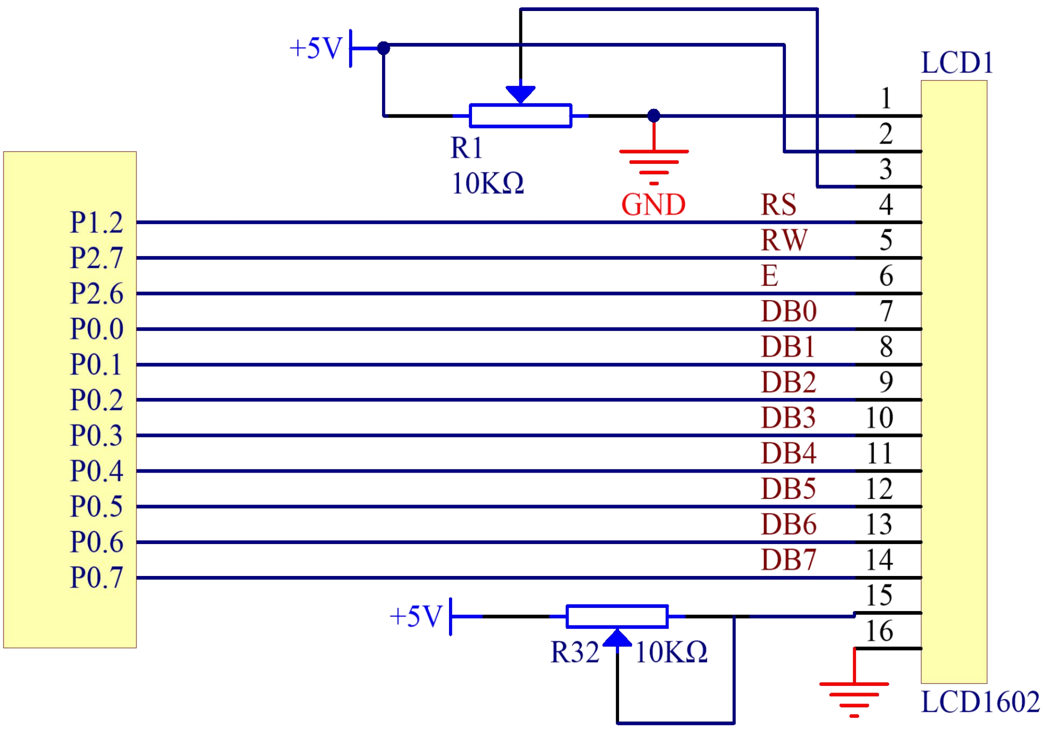

Figure 5: LCD wiring diagram

IV. Overall Circuit Design of the System

Different sources of power supply, will be doped with a lot of clutter, and even voltage instability situation, therefore, the use of LM7805 voltage regulator module buffer from the transient response caused by voltage mutation, and then through the capacitor filter for the MCU power supply; According to the above hardware design, the crystal oscillator circuit, reset circuit and button circuit are added to obtain the overall circuit design diagram of the system, as shown in Figure 6:

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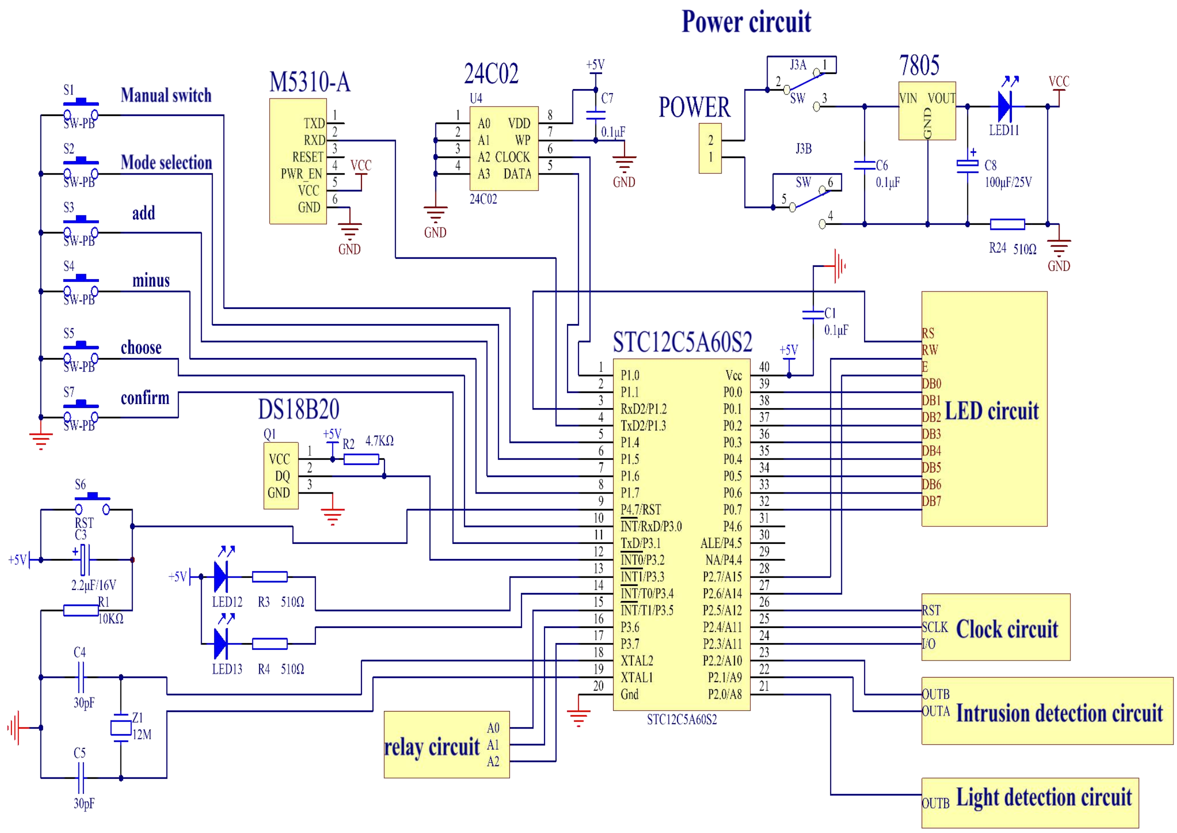

Figure 6: Overall circuit design of the system

V. System Software Design

5.1 Overall System Software Design

The system adopts Keil uVision4 development system in software programming, uses C language for programming, and uses STC program download software for single-chip computer program download.

After the system is powered on, initialization will take about 0.5s to complete the self-check and then formally enter the system. The system will first read the value of E2PROM, when the user began to set the number of classroom, then also replace the original data of E2PROM, and save; The system is divided into two modes, which are automatic mode and manual mode respectively. In the manual mode, the light can be directly controlled. In automatic mode, the user needs to set the lighting system startup time interval, beyond the specified time range will be forcibly shut down, the set parameters will be saved in the E2PROM, to prevent power loss; When the lighting time is satisfied, the light intensity is detected. If the light intensity does not meet the requirements, the light will not be turned on. When the light intensity conditions are met, the system will turn on the lighting in the corresponding area according to the number of people, and turn off the lighting when all people leave the classroom. The number of people and temperature information in the classroom will be uploaded to OneNet cloud platform by AT instructions sent to NBIoT to realize cloud visualization. The overall design flow chart of the system software is shown in Figure 7.

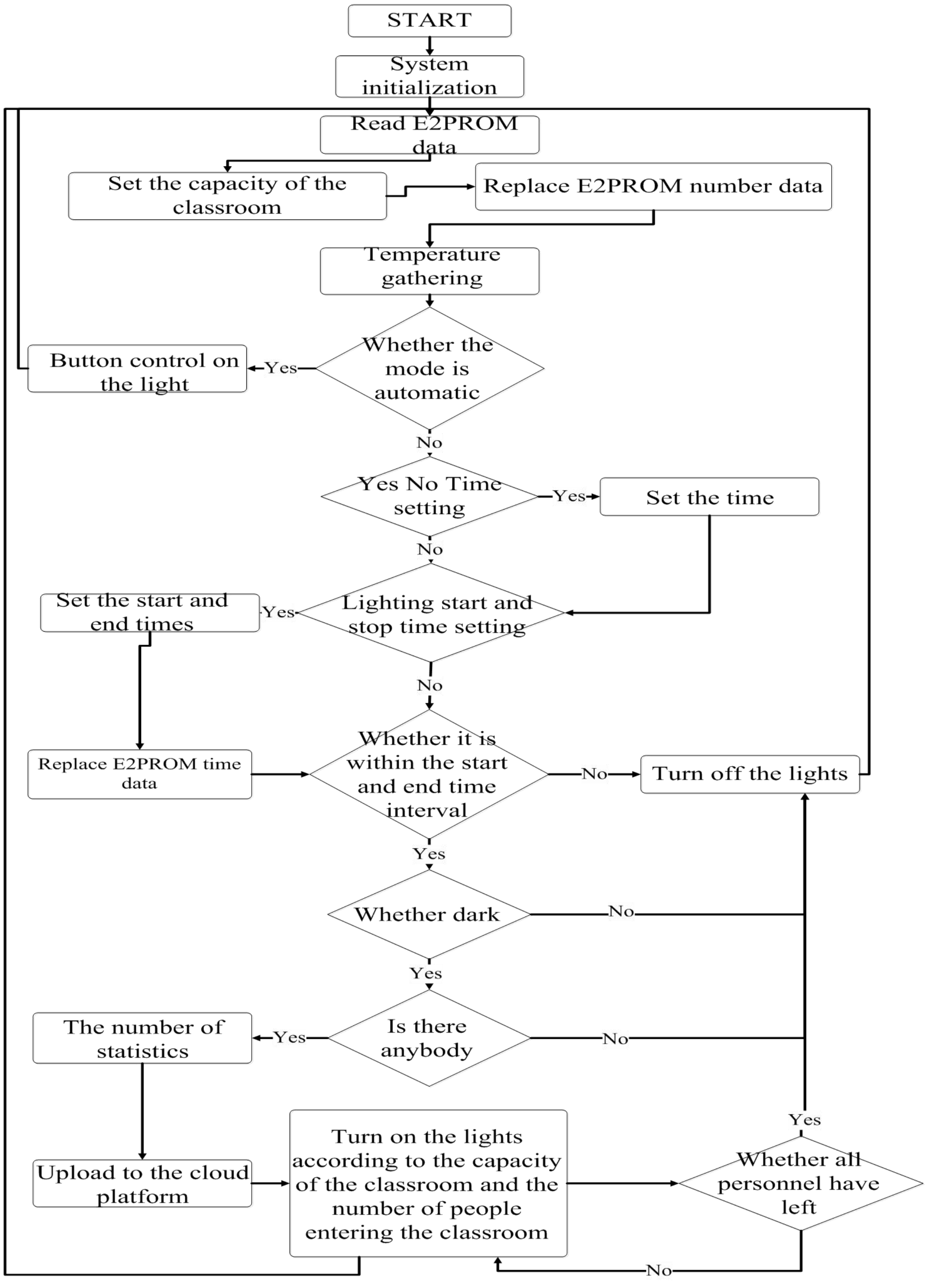

Figure 7: Flow chart of system software design

5.2 System Control Level Design

The control mode of the system is mainly divided into manual mode and automatic mode, which can be selected by pressing the key. In manual operation mode, the user can directly control the system through the button to turn on the light; In automatic mode, the system is divided into three control levels, of which the first level is the clock

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control, by setting the time interval, forced control device start and close; The second level of control is light control. Light intensity detection is carried out within the time range of system startup. When the light intensity falls below the set threshold, it enters the next control level. The third control level detects the number of people in the first two control conditions to meet the realization of the third light control level. If the first two control levels are not met, the system still detects the number of people, but do not turn on the light.

Set the status variable of the lamp to Z, Z=0 means on, Z=1 means off; A indicates whether it is within the working time range :A=1 yes, A=0 No. B indicates whether the light intensity meets the opening condition, B=1 meets, B=0 does not meet; C indicates whether personnel intrusion is detected. C=1 detected, C=0 not detected.
Control mode logic relation:

$$Z = A\&B\&C$$

Table 1: Lamp status logic truth table

Lamps and lanterns state Z	The clock control A	Light intensity control B	The number of control C
1	1	1	1
0	1	0	1
0	0	1	1
0	1	1	0
0	1	0	0
0	0	1	0
0	0	0	1
0	0	0	0

5.3 Design of Software for Population Detection

The system by two groups of infrared comments feedback signal is used to detect the number of tubes, two infrared tube respectively, both inside and outside the door, when the infrared on the tube outside first detected high level "1", gate of infrared detection after the tube to the "1" for someone to enter, is gaining one new person, when the door of the infrared testing the pipe to the "1", the infrared detection after the pipe to the outside "1", It means one person goes out, one person goes out. Enter the classroom for "1", "0"; The infrared matching tube outside the door is "OUT", and the infrared matching tube inside the door is "IN", as shown IN Table 2.

Table 2: Number of people detection logic control table

First detect high level "1"	**Post-detection high level is "1"**	**In/out of the classroom**
OUT	**IN**	**1**
IN	**OUT**	**0**

5.4 Energy-Saving Lighting Design

In order to achieve the purpose of energy saving, the system needs to open different numbers of lamps according to the number of classroom intruders, but the number of people in each classroom is different. To solve this problem, the system uses a certain number of lamps in different areas according to the number of people invading the classroom of different specifications. The classroom is divided into six areas. Users can set the number of people in the classroom by pressing the button. The system will turn on the lamps in the required area according to the proportion of the number of people. When someone enters the classroom, less than 10% of the number of people, it will turn on the first area lights, more than 10% of the number of people, less than 20% of the first and second area lights, each 10% increase, one more area lights, when the number of people reached 51% of the total number of people in the classroom, the classroom lights will be all on. The distribution of classrooms is shown in Figure 8.

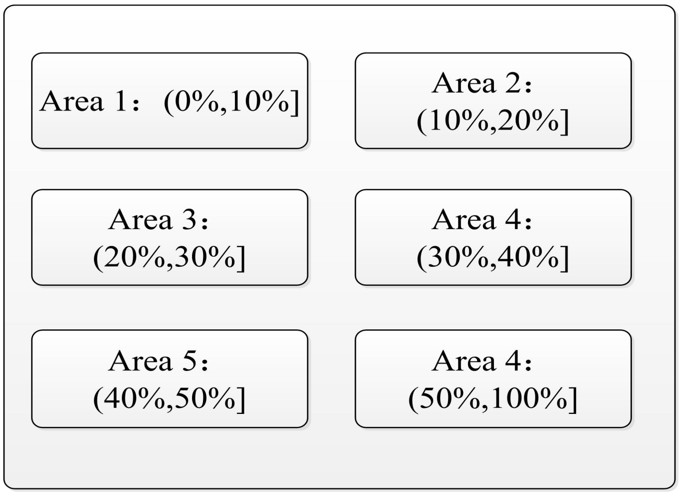

Figure 8: Regional distribution of classrooms

VI. Cloud Platform Design

The classroom status visual query system is designed based on OneNet platform, which is an open platform of PaaS Internet of Things created by China Mobile. The lower computer sends corresponding AT instructions to NBIoT and other modules through single chip microcomputer to connect the API interface. The platform supports LwM2N, MQTT, TCP, EDP and HTTP protocols. This system uses M5310A to communicate with LwM2N, which greatly reduces the developer's r&d, operation and maintenance costs. Users can customize applications independently according to the product and service framework provided by OneNet platform, as shown in Figure 9. The users, products, devices, APIkeys, triggers, and data flows of the OneNet platform are structured as shown in Figure 10[21].

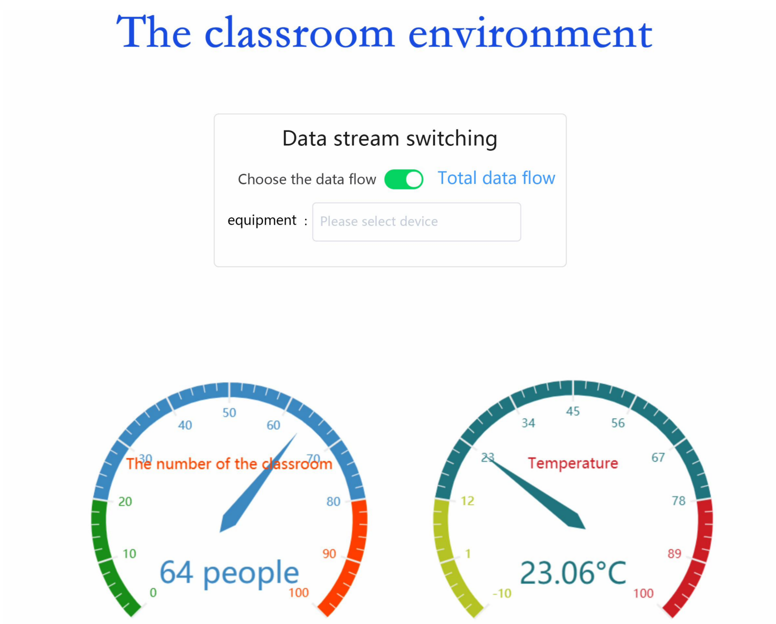

Figure 9: Onenet platform application interface

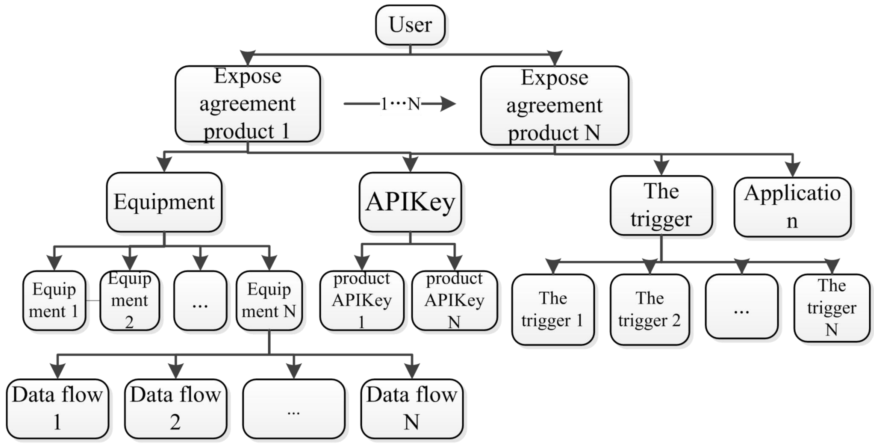

Figure 10: Onenet platform resource management hierarchy

VII. Test and Analysis:

Put on the system in different simulated test, the classroom found in different light intensity in the classroom, while the photosensitive resistance can be adjusted according to the requirements of the classroom environment sensitivity, but the light intensity of infrared tube has a great impact on the accuracy of recognition, and the practical application of people do not always go according to light intensity repeatedly sensitivity adjustment precision to ensure that the number of queries. In order to solve this problem, it is necessary to add shading device in the infrared pair tube of the system to ensure the accuracy of identification. Therefore, our team selected thick black rubber cover as shading material for testing. According to the investigation of a large number of classroom data in different time periods, the lowest light intensity of classroom doorway is 11.2lx, and the highest light intensity is 1904.4lx. To this end, the system was tested under five different light intensity intervals, which were divided into two conditions: one was with shading and the other was without. Under the same sensitivity, 50 people were entered into the classroom respectively, and the accuracy test of population detection was conducted (the test times were more than 20 times), and the test results were shown in Table 3. The light testing software adopts professional mobile phone hardware testing APP: Dev Check.

Table 3: Light intensity test table

Light intensity（/Lx）	Actual number of entrants（/PPL）	Number of people who did not join the visor test（/PPL）	Add the visor to detect the number of people（/PPL）
10~100	50	50	50
100~500	50	48	50
500~1000	50	44	50
1000~1500	50	40	50
1500~2000	50	33	50

According to the test results in Table 3, the addition of the shading device greatly improves the anti-light interference performance and ensures the accuracy of the number of people detected.

VIII. Conclusion

This design is based on the STC12C5A60S2 single-chip microcomputer as the core of the control system, through the software and hardware cooperation, the use of cloud platform as a visual query tool, in order to open the time, light intensity, the number of detection three-layer strategy control method, to achieve the purpose of classroom

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energy-saving lighting. And realize the function of allowing students to query the relatively comfortable self-study classroom and the statistics of teachers' attendance. The addition of memory of power outage solves the problem of lost set parameters caused by power outage, and the addition of innovative shading device greatly improves the accuracy of classroom number detection. The system greatly improves the utilization rate of classroom lighting space, prolongs the service life of lamps and lanterns, and saves a lot of energy. After many experiments and tests, the system runs stably and responds quickly. The equipment can also be applied to meeting rooms and other venues after some appropriate adjustments. It conforms to the development of the era of high efficiency, energy saving and digitalization, and has important value for the future development.

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