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Wireless Smart Home System Based On Zigbee

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Abstract

With the rapid development of modern science and technology, people have higher and higher requirement for living environment. To achieve the purpose of intelligence, convenience and comfortability in smart home, this article has designed a wireless smart home system. This system adopts S3C6410 as its controlling core and Zigbee technique as wireless data transmission and has achieved control over lighting, curtain and common household appliances in the house. This article also gives the design of main software and hardware. This system is proven to be stable, easy and simple to handle and easy to extend after testing and now has been applied in many residential areas.

Keywords*: Zigbee smart home S3C6410 sensor*

1. Introduction

With the raid development of communication technology, Internet of Things technology and embedded technology, various automatic and intelligent products seem to emerge in an endless stream, tremendously changing people's lifestyle and promoting people's wish for higher living quality. It has become an ideal choice to achieve smart home system using wireless communication technology to control over household facilities. Wireless communication control has advantages in installation and wiring. Therefore, the smart home system using wireless communication technology to realize the control over household facilities can better satisfy the need of people for intelligent life without destroying the existing decoration and reducing the wiring indoors [1-2]. Consequently, this article designs a smart home controlling system that is lowcost, low power dissipation and easy and simple to handle.

2. Overall Design of Smart Home

The smart home system that is studied in this task employs S3C6410 as core controller and achieves the intercommunication between the mainframe and functional modules by Zigbee wireless module inside and finally realized the intelligent control over household facilities. The structure chart of the overall system is shown in Figure 1.

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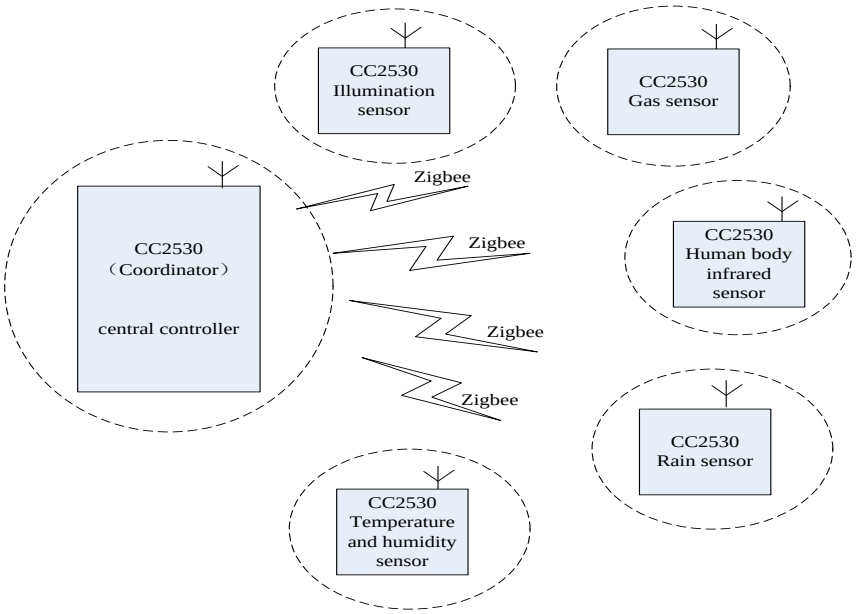

Figure 1. Structure Chart of the Overall System

2.1. Zigbee Wireless Transmission

The main functional units for wireless in Zigbee are terminal node and coordinator, which both belong to micro embedded system, mainly composed by processor module, wireless communication module, power module and corresponding debugging interface. In addition, sensor module and light controlling module need to be added in terminal node for the purpose of collecting environmental information and controlling the lighting [4].

CC2530 combines an entirely integrated and high-performance RF transceiver and a 8051 micro processor and is provided with flash memory as high as 256k and link quality of 101db. CC2530 has relatively high receiver sensitivity and anti-interference capability and is provided with four power supply modes. This CC2530 is also equipped with a TI standard-compatible Z-Stack network protocol stack to simplify the development work. CC2530 working system only needs a small amount of external auxiliary components. In real application, if we establish wireless network only on the basis of CC2530, the distance between nodes will be limited within 100m. According to the practical application experience in home environment, we cannot meet the ideal requirements using only CC2540 chip, so we choose to use CC2592 RF front-end as the range extender of the RF unit [6]. CC2592 is an affordable but high-performance RF front-end aiming at the low power dissipation and 2.4GHz low voltage wireless application, aiming at all CC25XX 2. 4GHz low voltage transceivers, transmitters and range extenders of system products in TI. To increase link budget, CC2592 provides a power amplifier that can increase output power and LNA that has low noise figure to improve the sensitivity of the receiver. Compared with CC2590, it has a wider range of working temperature and has made great improvement in the efficiency of the power amplifier [12]. The maximum output power of CC2530 is +4. 5dBm. However, the output power can reach +22dBm after adding the CC2592 range extender. The distances between nodes are increased and the extended range of wireless network can fully satisfy the need of system design. The circuit diagrams of CC2530 and CC2592 are shown in Figure 2.

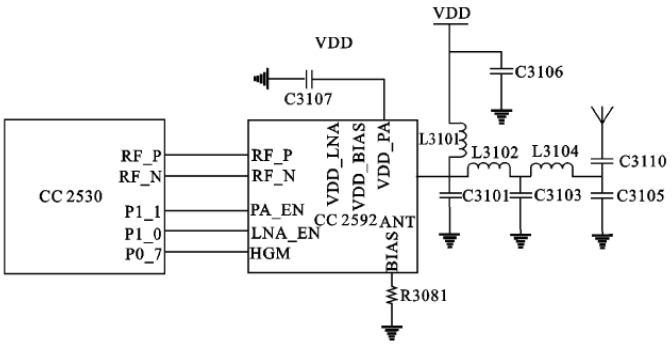

Figure 2. Circuit Diagrams of CC2530 and CC2592

2.2. Core Controller S3C6410

S3C6410 is a kind of high cost performance and low power dissipation 16/32-bit RSIC micro processor launched by Samsung company based on core ARM11, most of which are applied in mobile phone and common domain. S3C6410 has adopted the 64/32-bit internal bus architecture made up of AXI\AHBTAPB bus to provide the best hardware performance. The following resources are integrated within the chip: one LCD controller, SDRAM controller, NAND Flash controller, UART interface supporting four channels, 32-channel DMA, 4-channel counter possessing PWM function, one internal clock, full-featured SPI, IIC bus interface, IIS digital audio bus interface, three PLL, 3-channel MMC/SD controller and so on [10].

The circuit of the central controller mainly includes: Wi-Fi module circuit, Zigbee module circuit, Ethernet module circuit and memory module circuit. The core structure is shown in Figure 3.

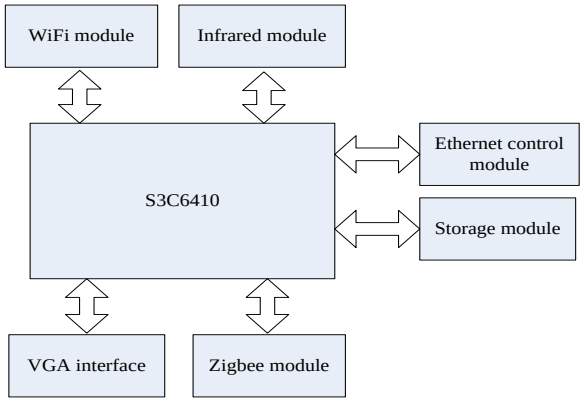

Figure 3. Core Structure

2.3. Sensor Modules

2.3.1. Circuit Design of Gas Sensor: At the moment, common gas sensors we can see include: semi-conductive type gas sensor, electrochemical gas sensor, infrared gas sensor, contact-burning type gas sensor and so on. The structure of semi-conductive type gas sensor is to adopt sensing elements made from metal oxide semiconductor or metal oxide material. The structural material and the gas interact with each other and trigger surface reaction to lead to the change in electric conductivity, thus causing the change in electric potential. The gas sensor module in this system employs resistance-type semi-conductive gas sensor as its sensing elements in hardware circuit design. It is a kind of impedance device made from metal oxide film, whose resistance will change based on the gas content. For example, the resistance will increase as the concentration of gas rises and

vice versa [3]. It has many advantages, like low cost, high sensitivity, long using time, simple manufacture and simple application circuit. The schematic circuit diagram of the gas sensor is shown in Figure 4.

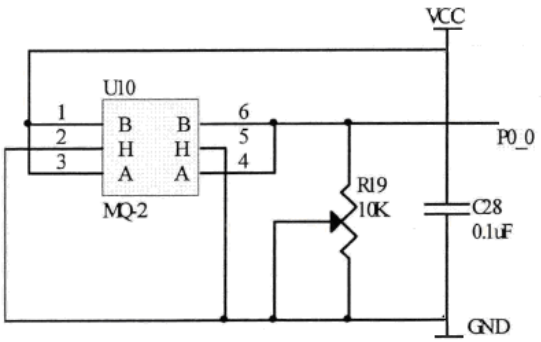

Figure 4. Circuit of Gas Sensor

2.3.2. Circuit Design of Temperature and Humidity Sensor: The selection of temperature and humidity sensor, as important components in the data collection of the system, exerts direct influence on the precision and accuracy of data collection. In the early stage, we usually adopt stimulative temperature and humidity sensor to collect temperature and humidity respectively. Although this meet the situation where the requirement for precision is not high and single point measurement, yet this will not satisfy the situation where the requirement for precision is high and multi-point measurement. With the rapid development of electronic technique, digital temperature and humidity sensor is produced. It can collect the information of temperature and humidity at the same time and transmit the information in digital quantity. The sensor has been examined before leaving the factory, so the user doesn't have to examine it when using, which means it will be more convenient in the application of temperature and humidity monitoring [7].

The temperature and humidity sensor in this system chooses STH10, which is a kind of high-integrated digital temperature and humidity sensor produced by Sensirion Company in Switzerland and can be used in collecting the surrounding temperature and humidity. In the circuit, we connect the SCK foot of SHT10 with P0_0 foot of CC2530, which is for synchronizing the communication between CC2530 and SHT10; the output Data of SHT10 is serially transmitted to the P0_6 interface of CC2530 in order under the control of SCK clock; in the process of data transmission, we connect a 4.7K pull-up resistor to the SHT10 serial data output line to avoid the conflict of transmitted data. The detailed circuit diagram is shown in Figure 5.

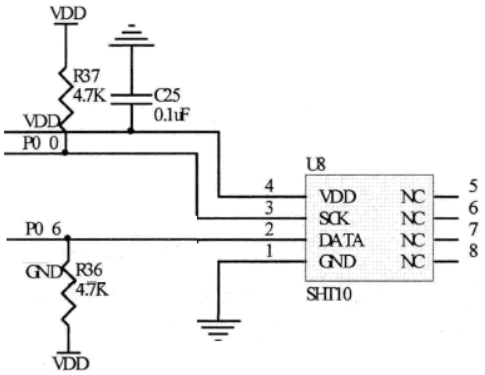

Figure 5. Circuit Diagram of Temperature and Humidity Sensor

2.3.3. Circuit Design of Illumination Sensor: The function of illumination sensor is to collect the data of illumination intensity within the house, so as to achieve the automatic control over lighting and curtain. In the circuit design of this system, we choose the photoresistance as illumination sensor and the circuit design is shown in Figure 6. In the circuit design, we connect a 1k resistance R2 in series to the front end of photoresistance, constituting a voltage division circuit. When the illumination intensity is weakened, the value of resistance will increase, then the voltage sent by the point 1 in the circuit to the P0_0 junction of J18 will increase. On the contrary, if the voltage goes down, the P0_0 junction of J18 is actually connected to the P0_0 interface of CC2530, namely the A/D converted analog voltage input port. In the CC2530, we convert the change of voltage to digital quantity through A/D analog-digital conversion. In this way, we can reflect the change of illumination intensity by numerical value [4].

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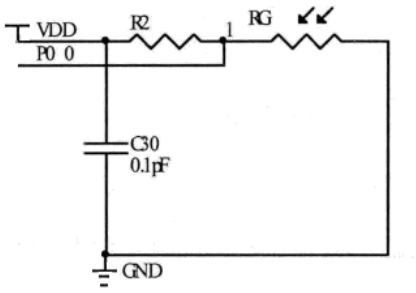

Figure 6. Circuit Diagram of Illumination Sensor

2.3.4. Circuit Design of Raindrop Sensor: The raindrop sensor, which is also called rain detection sensor, is used to detected whether it is raining or not and the amount of rainfall. The raindrop sensor in this system is to achieve the automatic closing of window or curtain, preventing the rain from drifting inside the house. The circuit diagram of raindrop sensor is shown in Figure 7.

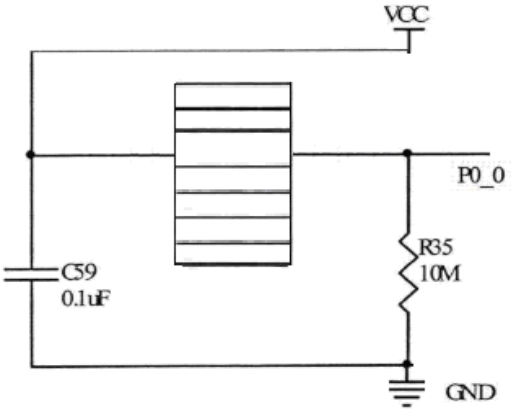

Figure 7. Circuit Diagram of Raindrop Sensor

2.3.5. Circuit Design of Infrared Sensor of the Human Body: Infrared sensor of the human body is a kind of electrothermic type infrared sensor based on the principle of electrothermic effect, which can detect the thermal infrared wave from

human body. In the design of this circuit diagram, we apply the GH-718 infrared induction module, the working voltage of which is 5V and the output is switching value (high level 3.3V). The biggest detection angle of this sensor is 110°and the longest detection distance is 7m. The schematic circuit diagram is shown in Figure 8.

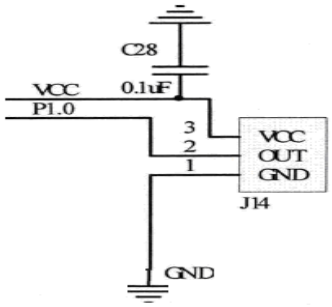

Figure 8. Circuit Diagram of Infrared Sensor of the Human Body

2.3.6. Circuit Design of Household Appliances Control: The household appliances control can not only adopt the relay controlling module to control the power supply and power down of household appliances. In this system, we also design an infrared household appliances controlling module, which is made up of infrared receiver circuit and infrared emitting circuit. The circuit design of this module is shown in Figure 9.

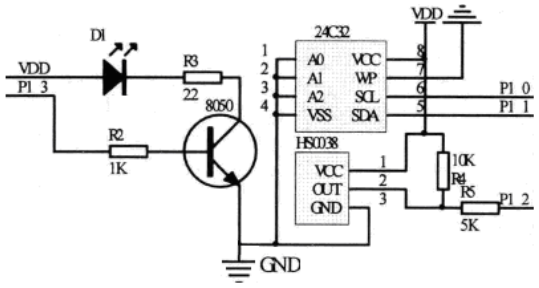

Figure 9. Circuit Diagram of Household Appliances Control

2.3.7. Circuit Design of Memory: Memory module is used for the storage of real time data. When powering down, it can store the data collected and save it in the central controlling center, which is convenient for the checking the real time status between different networks.

This system employs 24C64 as the memory chip. FM24C64 is a kind of serial nonvolatile memory. The logical structure is 8192*8 bit and the interface mode is the two-were interface in compliance with industry standards. The functional operation is similar to serial EEPROM, however, the writing speed of ferroelectric memory is much faster than that of the EEPROM and it has not time delay [9]. The introduction to the 24C64 pin is shown in Table 1 and the circuit design is shown in Figure 10.

Table 1. Introduction to 24C64 Pin

Name	I/O	Description
A0-A2	Input	Address 0-2: FM24C04 physical address. The device value of the address in the two-line protocol should be the same as the signal of the two feet.
SDA	I/O	Serial data/address: in the two-line protocol, this is a bidirectional data line used for transmitting serial data and address. It is open-drain output and can be connected to other devices on the two-line bus or be added pull-up resistor if needed.

SCL	Input	Serial clock: two-line interface serial clock input. The data is transmitted on the falling edge of SCL. The data can be transmitted on the rising edge of SCL if added pull-up resistor.
WP	Input	Write-protection: the WP is high level. The address of write-protection varies from 100H to 1FFH. FM24C64 will not respond to the data written in the protected address. If the WP is low level, these characteristics will not work. WP pin-out should not be suspended.
NC	NC	NC
VDD	Power Supply	Power supply voltage: 5V

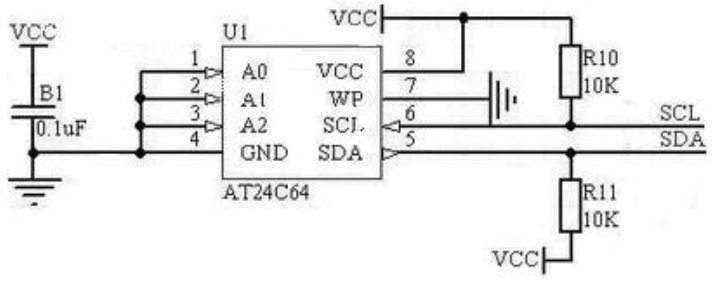

Figure 10. Circuit Design of 24C64

2.3.8. Alarming Circuit: The alarming circuit is designed specially for security mode. A 1k ohm resistance will be added to the pin of processor GPB3 and will be connected to the base of audion. When the GPB3 port is low level, namely the base is low level, the audion is breakover and drives the buzzer to send out alarm sound to show the abnormality indoors. If the GPB3 port is high level, namely the base is high level, the audion is cut off and the buzzer will not work to show there is no abnormality indoors. The schematic circuit diagram of the alarming is shown in Figure 11.

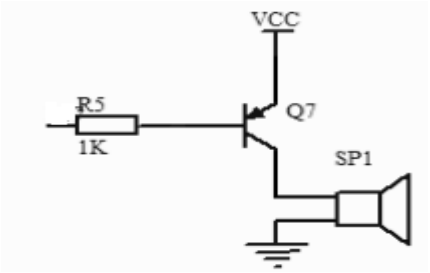

Figure 11. Schematic Circuit Diagram of the Alarming

3. Design of the System Software

In the software development of this system, we use C programming language to modify the applications in the general module of CC2530 protocol stack in order to establish the program that we need and to complete the software development of Zigbee wireless sensor data transmission in this system. The main software in this system is divided into the coordinator node software and terminal node software. Although they differ in function, but the configuration of the network parameters and the application framework construction are the same. Therefore, in the software design, we firstly carry out the construction of wireless sensor network software platform, and then conduct the configuration and design of coordinator node and terminal node on the platform that has

already been built. In this way, we complete the design of coordinator node and terminal node software. The analysis of main software function is as follow.

3.1. Software Design of Coordinator Node

The main task of the coordinator, the first node equipment of Zigbee network, is to establish the Zigbee network, preserve the normal operation of Zigbee network. The coordinator can also allow the terminal node to freely join and leave the network and the coordinator is responsible for the data transmission between the terminal node and core controller. The route chart of coordinator node is shown in Figure 12.

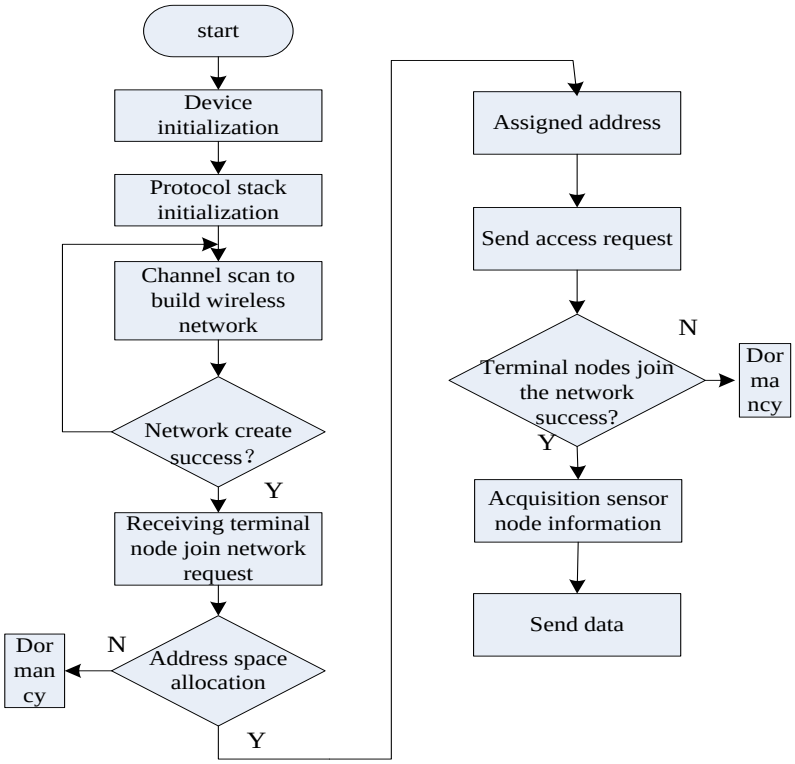

Figure 12. Route Chart of Coordinator Node

3.2. Software Design of Terminal Node

The software design of Zigbee terminal node include joining the network, driving all kinds of sensors (controlling node) and the transmission of data. The terminal node starts to drive the sensor to collect data after joining the network and packs the data to transmit to the coordinator. The route chart of terminal node is shown in Figure 13.

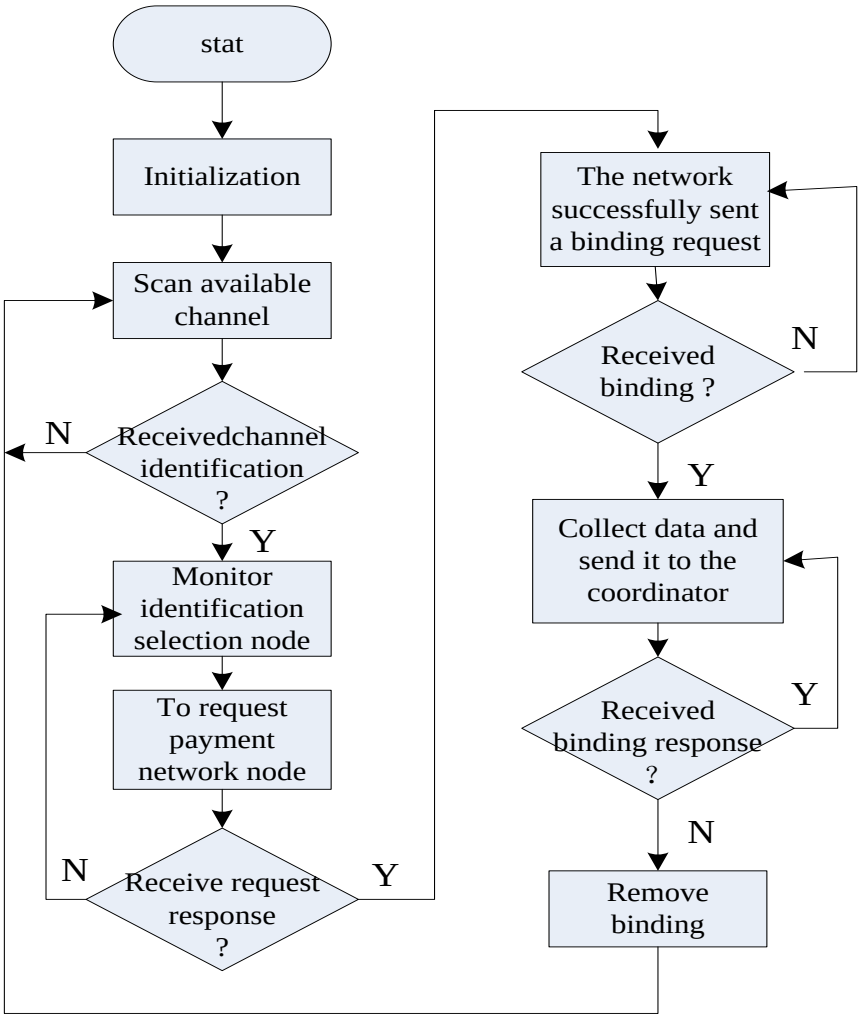

Figure 13. Route Chart of Terminal Node

3.3. Software Design of Illumination Sensor

In the hardware circuit design of illumination sensor node, we convert the change of illumination intensity into the change in voltage and then send to the P0_O port of CC2530 chip. Through the analog-digital converter inside the chip, we convert the analog voltage into digital signal, thus indirectly turn the illumination information into digital signal. Then we can tell the current illumination situation by judging numerical value after the conversion in the programming design. The programming flow chart of illumination sensor node is shown in Figure 14.

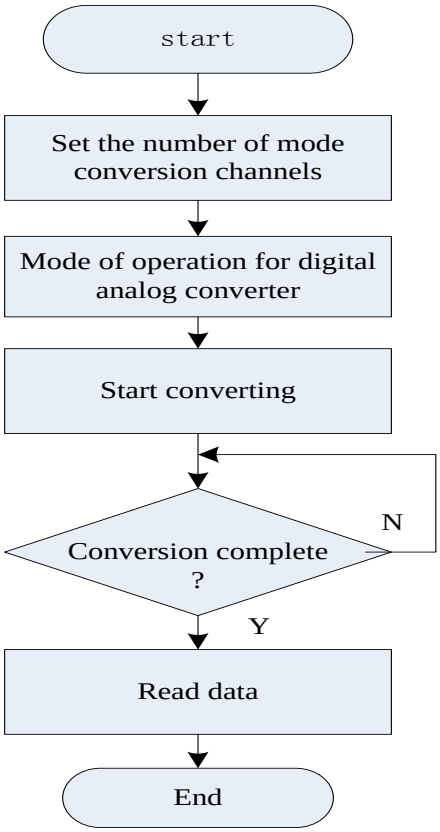

Figure 14. Software Flow Chart of Illumination Sensor

3.4 Software Design of Temperature and Humidity

In the programming of the driver of temperature and humidity sensor node, we write the initialization function SHT10_init(unsigned int Initial—Reg), the byte writing function SHT10_WriteByte(unsigned char data) and the data-processing function SHT10_Calculate(unsigned int data, unsigned char mode) for SHT10 temperature and humidity sensor based on the initialization sequence chart, data-reading sequence chart, data-writing sequence chart and the command set; when the CC2530 communicates with the SHTIO temperature and humidity sensor, we need to initialize the SHTIO temperature and humidity sensor first, then write the command (read/write status register, temperature measurement and humidity measurement), and finally wait for the completion of data conversion. The program flow chart of the SHTIO temperature and humidity sensor driver is shown in Figure 15.

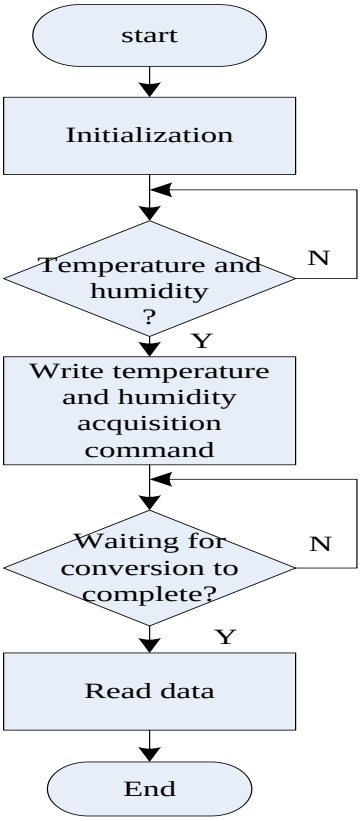

Figure 15. Software Flow Chart of Temperature and Humidity

4. System Testing

We successfully built a star network, a coordinator and many terminal nodes based on Zigbee protocol. The coordinator is responsible for establishing the network. The terminal node can achieve the communication with the coordinator after connecting to the network. We conduct testing on the data receiving and transmitting between the coordinator and network node through serial port. The network communication method of terminal node when receiving data is broadcasting and the coordinator sends one byte of data to the network terminal node every 300s. The network communication method of the coordinator when receiving data is on-demand and the terminal node sends one byte of data to the network coordinator every 300s. The result of the testing is shown in Table 2.

Table 2 Packet Loss Rate and Bit Error Rate of Zigbee Transmission

Device Type	Times of Test	Times of Packet Loss	Times of Bit Error	Packet Loss Rate (%)	Bit Error Rate (%)
Coordinator	300	2	1	0.67	0.33
Temperature and Humidity Sensor Node	300	1	0	0.33	0
Gas Sensor Node	300	1	0	0.33	0
Raindrop Sensor Node	300	0	1	0	0.33
Infrared Sensor Node	300	1	1	0.33	0.33

We can see from the result of the test that the stability of Zigbee data transmission is relatively high and can operate stably and normally in the newly decorated houses.

5. Conclusion

The application of Zigbee in the field of smart home is continuously innovated and developed. This article proposes a Zigbee wireless smart home controlling system based on the advantages of low cost, low power dissipation and flexible use of Zigbee wireless communication technology. This article explains in detail the design of Zigbee sensor node, the networking mode and the software flow of sensor data transmission under the environment of smart home. The result of the testing has shown that the wireless data transmission of this system is stable and reliable and has achieved wireless intelligent control, bringing broad application prospect for the development of smart home field.

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