Smart Home Wireless Alarm System Based on 2.4G Nrf24l01 Wireless Networks

Shuxing Zhang
Kunming University of Science and Technology, Kunming, Yunnan, China

Qun Yin*
Kunming University of Science and Technology, Kunming, Yunnan, China
*Corresponding author (E-mail: 455601875@qq.com)

Jianbo Zhang
Oxbridge College, Kunming University of Science and Technology, Kunming Yunnan, China

Si Liu
Xiangtan University, Xiangtan, Hunan, China

Abstract
This article devises a fully functioning smart home wireless alarm system, and the system is based on the 2.4G wireless networks. It mainly made by the alarm from the machine and alarm from the host two major forms. For alarm from the machine, it includes information collection circuit composed of various types of sensor probe and STC12C5A60S2 MCU and nRF24L01 wireless transmission module. It can collect the temperature and humidity, gas leak, fire, smoke, hacking information, and then it will collect the information through the wireless transmission to the terminal alarm host. For alarm host, it includes sound and light alarm, buzzer and STC12C5A60S2 microelectronics consisting of circuits and nRF24L01 wireless receiver module. Alarm host can receive alarm signal from the wireless transmission and process it to make the alarm action. The system has a responsive, wide detection range, and inexpensive. It is suitable for the vast majority of families as a home alarm use.

Key words: STC Single-chip Microcomputer, Wireless Alarm System, Sensor Module, Sound and Light Alarm Circuit, NRF24L01 Wireless Networks.

1. INTRODUCTION
With the development of the society and the rise of people living standard, all kinds of daily equipment maybe cause many safety problems. For example, there are gas leak, fire, water pipe burst, and so on. If it cannot timely rescue when those events happen, it will cause big loss of the personal and property safety. So as the basic unit of the society, family security issues is particularly important. High-tech household anti-theft security alarm system has increasingly widespread attention and application.(Wang and Dong, 2011).

At present, the security alarm has various researches at home and abroad, and the overseas technical level is already high. North America's most successful business model is the networking alarm service mode. At the same time, it combines a large number of network management technology, system integration technology and electronic technology. And it has become a very advanced networking alarm service platform. Because of the means of domestic communication and industrial development level, especially the chip in our country failed to catch up with the international level, the domestic security technology is still at a relatively low level.

A well-known brand in the security market is mostly imported abroad, and widely used in some new district. Linear products have some advantages that special line, stable performance, and no power supply problems. But there are problems in the whole structure and local severe about linear products. In addition, the user wants to improve some new functions, but they don’t know how to do it. So the market of wireless products is arises at the historic moment, and it can solve all problems above. But such expensive imported products are not suitable for family use, and the current wireless products in global market are the ITT series of the American general intelligent company, however, it is specializing in the production of American wireless alarm products and product price is very expensive.

Since the middle of the 20th century, the third technological revolution has begun to rise, it brings human society into the electronic information age. In the 21st century, humanity has full access to electronic information age, people are inseparable from the information technology. There are also many household devices bring security danger that hidden in people's daily life at the same time. In addition, the social security situation in many cities is bad, and the people under a lot of personal and property security threat. At the present...
social environment, it is necessary that create an alarm system for people, and it can be used in the vast majority of families and communities. Nowadays, the traditional security bar affects buildings not only beautiful, but also exist safety hazard, and the wired alarm way exists a complex wiring, this wiring is easy aging, and line fault is difficult to troubleshoot, etc. Smart home wireless alarm system based on 2.4 G technology can solve the above problems.

There are the following advantages compared with the traditional mechanical security system: (1) it does not affect the beautiful and clean of city building. (2) It does not affect the fire rescue channel. (3) It does not provide convenience conditions to the criminal. (4) There will not be in danger of falling objects after a long time.

It can real-time monitoring the safety of the whole household environment, it can monitor scope including indoor security, fire alarm, gas leak, the pipe burst and a series of insecurity factors. Once there are the safety accidents, the alarm system will give the corresponding alarm information, and it can take effective emergency measures immediately after the alarm information, it also can handle accidents in emergency and reduce the loss of the personal and property safety. In addition, the design of alarm system research and implementation has a certain practical significance and practical value, and it has certain influence on the development of security companies.

2. SYSTEM DESIGN

2.1. The Overall System Design Diagram

The overall system including alarm slave and alarm master machine, they through wireless network for data transmission.

(1) alarm slave machine include: it design the information acquisition and process circuit for the whole household environment monitoring through the temperature and humidity sensor DHT11, the gas leak detection sensor respectively MQ-5, the smoke sensor MQ-2, and the human body infrared detection sensor RE200B. Besides, it uses the wireless module nRF24L01(Tong, 2012), which send abnormal signal to the mainframe by means of wireless network transmission.

(2) The alarm host machine include: it realize sound and light alarm, and the function of the alarm message real-time display. It uses LED and buzzer to design sound and light alarm circuit, uses LCD12864 display shows alarm information, and uses nRF24L01 wireless module receive information from slave machine. STC microcontroller scan whether the wireless module receive or not, if the wireless module receives the alarm information from slave machine, the STC micro-controller will to deal with information, drive the sound and light alarm circuit to alarm and real-time display alarm information.

(3) The overall system uses the STC micro-controller as the main control chip, which combining nRF24L01 wireless module for wireless transmission data exchange.

2.2. The Overall Block Diagram of System

The Overall Block Diagram of System can be shown as Figure 1, Figure 2, and Figure 3.
3. HARDWARE DESIGN

3.1. Temperature and Humidity Sensor

DHT11 is a single bus bi-directional serial data transmission sensor, information acquisition circuit is very simple, Pin 1 is to connect power, and the power supply voltage from 3 V to 5.5 V, pin 4 connect ground (Chen and Liu, 2014). Pin 2 is the data port, which have data communication with the processor MCU, and connecting I/O port of MCU, when attachment is less than 20 meters, that need to pick up 5 k pull-up resistors, if higher than 20 meters, it need the actual situation to choose the appropriate pull-up resistors, and pin 3 hung up. In the practical application, the power supply pins (VDD, GND) connect a 100n capacitance indirectly, that used for decoupling filtering, and improve the circuit performance. Temperature and humidity acquisition circuit is as shown in Figure 4.
MzLH04 is serial SPI interface, the circuit connection is very simple, the interface circuit is shown followed, then single chip microcomputer deal with the temperature and humidity information which are collected by sensor, and driver LCD12864 display (Veleva and Davcev, 2012). Temperature and humidity display interface circuit is as shown in Figure 5.

![Temperature and humidity display interface circuit](image)

**Figure 5.** Temperature and humidity display interface circuit

### 3.2. Gas Leak Detection Circuit Design

ZYMQ - 5 gas sensor working principle is: under the environment of different concentrations of gas sensor, have different resistance, which can be regarded as a variable resistor. Attaches the sensor and a partial pressure resistance in series on both ends of the power supply, gas sensor resistance R_MQ-5 resistance along with the change of gas concentration, and the partial pressure ratio will be along with the changes, the output voltage also can follow the gas concentration changes (Xu and Hu, 2013). To design circuit and deal with the change of the output voltage value, it can achieve the purpose of the gas leak detection. Partial pressure sensor circuit is as shown in Figure 6.

![Partial pressure sensor circuit](image)

**Figure 6.** Partial pressure sensor circuit

Professional voltage comparison device uses LM339 (Zhang and G. Z. Guo, 2015), general uses LM324, LM358, OP07 operational amplifier also can realize the voltage comparator. This design chooses OP07 operational amplifier for voltage comparator, processing output voltage signal of the sensor circuit, which realizes the gas detection and alarm function. Pin 2 of OP07 is the negative input, Pin 3 is positive input, Pin 6 is output, Pin 7 is positive power, and Pin 4 is negative power or GND. Voltage comparator is as shown in Figure 7.
OP07 operational amplifier is a dual power supply chip, using a single power supply, which has some problems in the output voltage, after the actual measurement, it is concluded that under the table 1 data:

### Table 1. The single-supply comparator

<table>
<thead>
<tr>
<th>Power</th>
<th>Compare</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin7—VCC (+5V)</td>
<td>Positive input voltage&gt;Negative input voltage</td>
<td>Voutput=+4.94V</td>
</tr>
<tr>
<td>Pin4—VCC (-5V)</td>
<td>Negative input voltage&gt;Positive input voltage</td>
<td>Voutput=-0.87V</td>
</tr>
</tbody>
</table>

Using a single power supply, the output side has the change of the high and low level, the high and low level can be used to produce square wave, or drive circuit. But low level + 1.4 V is still high, if send to SCM I/O port, make SCM detection would not be stable, because the STC micro-controller in this design, more than 2 V for high level, 0.8 V for low level. Between 0.8 V - 2 V state may be high or low, identification is not stable.Therefore, it need to improve scheme, one of the most effective way is to adopt double power supply, using dual power supply, after the actual measurement, it is concluded that under the table data, and gas leak detection complete circuit is as shown in Figure 8.

### Table 2. The double-supply comparator

<table>
<thead>
<tr>
<th>Power</th>
<th>Compare</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin7—VCC+5V</td>
<td>Positive input voltage&gt;Negative input voltage</td>
<td>Voutput=+4.94V</td>
</tr>
<tr>
<td>Pin4—VCC (-5V)</td>
<td>Negative input voltage&gt;Positive input voltage</td>
<td>Voutput=-0.87V</td>
</tr>
</tbody>
</table>

### 3.3. Smoke Detection Circuit Design

The principle of the ZYMQ - 2 smoke sensor is same with ZYMQ - 5, so the smoke detection circuit design has similar with gas detection circuit design, which only making a certain parameter changes(Faetti and Paradiso, 2013). Smoke detection complete circuit is as shown in Figure 9.
3.4. Human Body Infrared Sensor Design

There are two of the most common about the infrared anti-theft alarm: active and passive.

(1) The first scheme is active that was two probes, one adapts infrared transmitting tube to launch infrared light; another infrared receiving tube to detect the illegal invasion. This solution need to design a reflective processing circuit, and a receiving circuit.

(2) The second scheme is passive which only one probe, and not take the initiative to launch the infrared function, but detect the human body infrared spectrum to alarm. This scheme is only need to design a circuit, processing the signal of passive sensor probe.

Through the above two kinds of scheme comparison, found scheme2 is simple, low cost, high reliability, the software design is more simple, so this design adopts the scheme2 to achieve the implementation of human body detection alarm. Using RE200B (Hoey and Zakaria, 2012) infrared sensors to get the human body infrared signal acquisition, after BISS0001 chip processing to the single-chip microcomputer, micro-controller make corresponding operation, such as light lamp, and drive buzzer, etc.

According to the working principle of operational amplifier circuit, the multistage amplifier circuit voltage ratio is:

$$A_o = \frac{U_o}{U_i} \times \frac{U_2}{U_1} \ldots \frac{U_n}{U_{n-1}} \quad (1)$$

$$A_u = A_{u1} \times A_{u2} \ldots A_{uN} \quad (2)$$

And this formula means that the voltage amplification ratio of multistage amplifier circuit is equal to the product of all levels amplifying circuit voltage magnification ratio. So you can see it in the BIS0001 (Choi and Beom, 2013), the operational amplifier amplification gain:

$$A_{u1} = \frac{R_4}{R_1} \quad (3)$$

$$A_{u2} = \frac{R_6}{R_5} \quad (4)$$

The resistor R4 can adjust the size of the amplifier gain, information given in the manual is 10 K, but found in practical use, use the 3.3 K resistor, can improve the circuit gain to improve the circuit performance. Pin1 of BISS0001 connect GND, A = 0, which is not repeatable triggered ways of working. And a total gain in this circuit is 66 DB (Choi and Jie, 2014).
3.5. The Slave Machine Design

Using STC12C5A60S2 as the master control chip, scanning, read the information acquisition by sensor and processing the information, at the same time combining nRF24L01 module, send alarm signal by wireless to the alarm host, and realize remote alarm (Wei and Rim, 2012). Output delay time is determined by the value of the external R8 and C6, TI is determined by external R7 and C7, Operational amplifier amplification gain: the total gain of circuit is 66 DB. Through COP1 and COP2 after processing of two-way learning, the effective trigger signal detection Vs to start up latency timer, output signals (Kong and Liu, 2013). Slave machine connect circuit is as shown in Figure 10.

3.6. The Host Machine Design

Using STC12C5A60S2 as the master control chip, first reads the information acquisition by sensor and processing the information, if it receives the information, let the P0.5 get high level to control the LED, drive buzzer, achieve the function of sound and light alarm, and alarm message displayed on the LCD display in real time (Park and Lyu, 2012). Master machine connect circuit is as shown in Figure 11.
4. SYSTEM SOFTWARE DESIGN

4.1. Temperature and Humidity Information Acquisition Module Software Design

Figure 12. Temperature and humidity information acquisition module of the main program flow chart

MCU read data from sensor, first of all, P1.1 of MCU get high level and send the initial pulse signal to sensor and delay a period of time waiting for DHT11 response. If DHT11 response, began to receive data, no response continue to wait. Temperature and humidity information acquisition module of the main program flow chart is as shown in Figure 12.

The SCM for data conversion and drive LCD display, call RH() function, read the data, the data cannot be directly used to display, need to transform the data you receive, then calls the LCD driver function shows the temperature and humidity values.

The code of MCU for data conversion and drive LCD display

```c
RH();

displayRH = U8RH_data_H / 10;
disRH = U8RH_data_H % 10;
displayT = U8T_data_H / 10;
disT = U8T_data_H % 10;
for(i=0;i<20;i++)
    FontSet_cn(1,1);
    PutString_cn(10,5,"Welcome You!");
    PutString_cn(0,25,"humidity:");
    PutString_cn(0,45,"temperature:");
    FontSet(1,1);
    ShowChar(50,25,displayRH,1);
    ShowChar(50,45,displayT,1);
    PutString(65,25,".  %RH");
    PutString(65,45,".  ");
    PutChar(72,25,disRH+48);
    PutChar(72,45,disT+48);
    SetBackLight(100);
    Delay(20000);
```

4.2. The Gas Leak Detection Module

The SCM detect low level alarm code: damn circulation function in the main program, loop check I/O port, if the gas concentration is higher than a certain value, turn off safety light, turn on risk indicator light, said to detect gas leakage; On the other hand, turn on safety light, turn off risk indicator light. Gas leak detection main program flow chart is as shown in Figure 13.

The key code of SCM detect low level alarm

```c
while(1)
{
    if(DOUT==0)
    {
        //delay();
        if(DOUT==0)
        {
            LED1=1; LED2=0;
        }
    } else
    {
        LED1=0; LED2=1;
    }
}
```

4.3. Smoke Detection Module

The key code of SCM detect smoke alarm code

```c
while(1)
{
    if(DOUT==0)
    {
        //delay();
        if(DOUT==0)
        {
            LED1=1; LED2=0;
        }
    } else
    {
        LED1=0; LED2=1;
    }
}
```
The SCM detect low level alarm code: damn circulation function in the main program, loop check I/O port, if detected P3.3 port to lower level ,turn off safety light, turn on risk indicator light , said to detect smoke; On the other hand, turn on safety light, turn off risk indicator light .Smoke detection main program flow chart is as shown in Figure 14.

4.4. The Infrared Human Body Detection Module

The SCM detect high level alarm code: damn circulation function in the main program, loop check I/O port, if detected P3.3 port (signal==1) to high level, turn off “nobody” light, turn on “somebody broken into”indicator light. On the other hand, turn off “somebody broken into” light, turn on “nobody”indicator light. Use twice the "if signal (== 1) “for anti-interference.

4.5. Alarm Slave Machine Software Design
Figure 15. Alarm slave machine main program flow chart.

The key code of slave send data

```c
void nRF24L01_TxPacket(unsigned char * tx_buf) {
    CE=0;
    SPI_Write_Buf(WRITE_REG+RX_ADDR_P0,TX_ADDRESS,TX_ADR_WIDTH);
    SPI_Write_Buf(WR_TX_PLOAD, tx_buf, TX_PLOAD_WIDTH);
    SPI_RW_Reg(WRITE_REG + CONFIG, 0x0e);
    CE=1;
    inerDelay_us(20);
}
```

4.6. Alarm Host Machine Software Design

Code function: judging by reading a status register data reception, if (RX_DR) received data, just set CE to low level, after the read completion. The RX_DR, TX_DS, MAX_PT all set to high level, which to clear the interrupt flag. Alarm host machine main program flow chart is as shown in Figure 16.

The key code of host receive data

```c
unsigned char nRF24L01_RxPacket(unsigned char* rx_buf) {
    unsigned char revale=0;
    sta=SPI_Read(STATUS);
    if(RX_DR) {
        CE = 0;
        SPI_Read_Buf(RD_RX_PLOAD,rx_buf,TX_PLOAD_WIDTH);
        revale =1;
    }
    SPI_RW_Reg(WRITE_REG+STATUS,sta);
    return revale;
}
```
5. THE EXPERIMENTAL RESULTS ANALYSIS

5.1. Temperature and Humidity Information Acquisition Module Test

Temperature and humidity information acquisition module test has three problems, the problem analysis and solution is as follows:

(1) Single chip computer can’t read the DHT1 acquisition data correctly. Display of temperature and humidity data is not responsible with the current environment of temperature and humidity conditions (Chen, 2014).

The solution is: it modify the program, after the system is powered on, give single-chip microcomputer a starting pulse, and then make a delay then receive data from DHT11, in this way, can read the data correctly.

(2) Screen not display properly.

The solution is: it change display connects P2 of micro-controller. P0 port of SCM as the output general needs to pull resistance, the inside part of LCD does not wear resistance.

(3) Hardware circuit performance is not good, the real-time performance of temperature and humidity is bad.

The solution is: let the second pin of DHT11 connected resistors of 5 k to the micro-controller I/O port, because the connection between them less than 20 m, between power supply and GND add the capacitance of 100n, circuit work more stable and better performance.

5.2. Gas Leak Detection Module and Fire Smoke Detection Module Testing

Both module can use deflated simulation for gas leak, cigarette smoke was used to simulate the fire smoke test. When there is a gas leak, the module should detect the combustible gas, and lighting risk indicator. When the fire smoke detection module detects smoke lighting risk indicator.

Gas leak detection module and fire smoke detection module test, there are two problems, the problem analysis and solution is as follows:

(1) Sensor didn’t work properly. In the design of hardware circuit, for security reasons, the heating circuit of sensor string a protective resistance of 100 ohms. But power on, found that whether the gas leaked or not, the voltage does not change all the time. There may be two reasons: first, the sensor is damaged, it is unlikely; Second, and it is the circuit has a problem. To analyze circuits, this place has a problem, may be because the heating circuit in sensor didn’t work. Reviewed the MQ - 5 data manual (Yao and Lin, 2015), according to the formula: \( P = \frac{U^2}{R} \), calculating the heating power, heating resistance sensor itself had been enough.

The solution: cut the resistance. Again on the electrical debugging, it found the negative voltage can because small at the input because of a gas leak out.

Circuit cannot be indicate dander. Power on, but we found that the circuit did not work as expected, leakage indicator light will not instructions. Inspect single chip microcomputer connection part, found out the problem, we found that in the absence of a gas leak out, output has always been a high level, about 4.94 V voltage value, and the gas leaked, voltage is reduced, and the voltage is 1.4 V.

(3) The solution: check the manual used by SCM, the single chip microcomputer detection, the STC microcontroller in this design, more than 2 V for high level, and 0.8 V for low level. Between 0.8 V - 2 V state may be high or low, identification is not stable. Therefore, the circuit can appear sometimes directions can alarm sometimes can’t. So there are two solutions; one is the OP07 using dual power supply, another is to modify the positive side (Subramanian and Vijayalakshmi, 2014). Finally we choose the second. OP07 adopts double power supply, circuit can make the corresponding action on gas leakage, and work performance is very stable.

5.3. The Infrared Human Body Detection Module Test

Human body infrared detection module test has three problems, the problem analysis and solution is as follows:

(1) Modules can not realize detection alarm function. The original design is made signal processing and amplifying circuit by myself, however, it not achieve the function.

The solution: use a special infrared BISS0001 processing chip.

(2) The circuit work is not stable.

The solution: scanning the BISS0001 data manuals, we found the input port need a bias voltage of about 1 V, and pick up resistor of 47K when the resistance is connected, after the actual measurement, the bias voltage is 1.8 V, and it is changing. In addition, the activities of the human body is 0.1 Hz - 10 Hz frequency range. According to the formula:

\[
 f_H = \frac{1}{2\pi R_C} = 15.9 \text{ Hz (5)}
\]

\[
f_L = \frac{1}{2\pi RC} = 0.07 \text{ Hz (6)}
\]

So it design a band-pass filter, let the signal through a band-pass filter, and then into the first level operational amplifier amplification, again through the C2 and R5 coupled to the second operational amplifier filtering.

(3) Always indicate "someone is into".

The solution: BISS0001 chip A is connect GND, when A = "0", in the TX time any changes V2 are ignored, until the end of the TX time, so this called non-repeatable trigger work way. It can effectively restrain all kinds of interference. When choose repeatable triggered work way, A = "1", we found that the output signal is always high, not low down, the reason may be interference repeat trigger way will make the output has been effective, which has always been a high level. Therefore, we adopt the way of not repeatable triggered, pin1 of BISS0001 to connect GND.

5.4. Wireless Transmission System Test

Network formed by means of wireless transmission system, on each sensor module, set up wireless transmitting modules, on the terminal host to set up a wireless receiving module, forming a 1 to 4 the wireless communication network. The Yellow signal is CE, the green signal is IRQ, and it will send data to the FIFO buffer by SPI_Write_BUF function. The buffer send data through wireless. When IRQ signal is low level, which said the receiving node receive signals successfully. After it, the IRQ will convert the high level. The chart of CE and IRQ signal is as shown in Figure 17.

![Figure 17. The chart of CE and IRQ signal](image)

The green signal is SCK and yellow signal is IRQ (Khandelwal and Gupta, 2012). The first batch of green signal stand for node configuration process. After configuration signal, the CE is put high level, and the nRF24L01 start sending (or receiving) data, when data send (or receiving) completed, the IRQ get low level. The second batch of green signal stand for the process of nRF24L01. It spend time about 1 MS, which means communication success. The chart of nRF24L01 communication is as shown in Figure 18.

![Figure 18. The chart of nRF24L01 communication](image)
After configuration is complete, CE is high level and the data of launch node send out, the receiving node received the data successfully, the receiving node automatically launch ACK signal, IRQ get low level when launch node receives ACK signal, which said it communication successfully. The chart of SCK, IRQ and CE signal is as shown in Figure 19.

![Chart of SCK, IRQ and CE signal](image)

**Figure 19.** The chart of SCK, IRQ and CE signal

6. CONCLUSIONS

It is happy that we have completed four sensor detection circuit design, and have written the program and tested success.

Gas leak detection circuit can detect a combustible gas leakage and accurately instruct.

Fire smoke detection circuit detect combustible gas may happen occasionally false, but about the detection of smoke is also very sensitive and accurate. Combustible gas leakage and fire disaster also have some closely link, so the circuit is also effective for fire disaster detection. In general, the occasional combustible gas misstatement does not affect the normal use.

The human body infrared detection circuit is also very sensitive, and alarm accurately. But the shortcoming is that the detecting circuit need higher power supply demand, if the power supply is not stable, voltage fluctuation, the circuit will be cause false alarm. In addition, when the power start, about a minute or two minute the circuit is in unstable state, maybe appear the situation, that such as false positives or don't quote after power on. But when we wait a minute or two, it will return circuit over the unstable state, and it will achieve accurate human body detection alarm.

REFERENCES


