Research Article
Journal of Robotics and Automation Research

Design of thermal infrared sensing system for large space fire detection

Wei Wang, Yongjian Sun

Yongjian Sun. School of Electrical Engineering, University of Jinan, Shandong, 250022, P. R. China.

***Corresponding author**
Yongjian Sun. School of Electrical Engineering, University of Jinan, Shandong, 250022, P. R. China.

Submitted: 14 Mar 2022; **Accepted**: 26 Mar 2022; **Published**: 29 Mar 2022

Citation: *Wei Wang, Yongjian Sun. (2022). Design of thermal infrared sensing system for large space fire detection. J Robot Auto Res, 3(1), 112-116.*

Abstract
In this paper, a kind of infrared array sensor AMG8831 based on MEMS technology is selected, and it is suggested that the system should be applied to fire detection in large space. The principle of this system is to use infrared array sensor to take the temperature field in its field of view, and to analyze and judge the fire according to the change of temperature, which can basically avoid the shortcomings of the detectors used in large space.

Introduction
Research Background and Significance
Nowadays, with the development of the economy and the rise of the urban construction industry, all kinds of large-space buildings are also appearing more and more in people's daily lives, such as: stadiums, theaters, large shopping malls, auditoriums, convention centers, airport terminals, etc. This kind of large space building has the characteristics of high space, wide space, large fire load and so on[1]. Compared with ordinary buildings, this kind of large space buildings are obviously different in structure, so large space buildings also have greater fire risk than ordinary buildings[2].

The selection and installation of fire detectors in large space places are more cumbersome and not simple, coupled with the different flue gas flow laws after fires in large space places, these are the difficulties of large space fire detection technology. At present, the large-space fire detection technology includes infrared light thru-beam, laser thru-beam, suction alarm, single-point infrared sensor, large-scale infrared camera and image processing[3].

Research status at home and abroad
The uncooled infrared detector in the thermal infrared detector is widely used, and has the advantages of working at room temperature, responding to infrared radiation of various wavelengths, low production cost, and convenient operation[4],so it can be applied to non-contact temperature measurement. MEMS sensor is a new type of sensor, its manufacturing using microelectronics and micro-machining technology, compared to the traditional sensor, it has a small size, light weight, low power consumption, low cost, high reliability, suitable for mass production, easy to integrate and achieve intelligent characteristics [5].

The combination of MEMS and signal processing technology led to the further development of thermal infrared detectors, although research on micromechanical thermal infrared detectors has been underway since the development of MEMS technology in the late 1970s, but the progress of the practical application of thermal infrared detectors has been relatively slow. In 1982, the closed membrane structure of the silicon-based thermopile infrared detector made by G.R. Lahiji et al. of the University of Michigan in the United States was the first to combine the MEMS process with the production of thermopile infrared detector[6].

Nowadays, foreign infrared detection systems have developed quite well in terms of theory, system, method, technology or application . Compared with China, foreign infrared array sensors are more complete in research and development and production [7]. Domestic infrared detection technology is a period later than the start of foreign countries, from the first generation of infrared detectors only more than 40 years ago. Whether at home or abroad, infrared detection technology is due to its military needs and then promote its development [8], but infrared detectors can not only be used in the military field, but also in civilian, security and other fields have a wide range of applications. Micromechanical thermal infrared detectors are mainly used in non-contact temperature measurement, intrusion alarm, infrared imaging, gas analysis and other aspects[9].

The Overall Scheme Design of the System
The system is mainly composed of micro-mechanical thermo-infrared array sensors, microcontrollers, serial communication modules and PC mechanisms. The system first connects the micro-mechanical thermoirographic infrared array sensor and the

microcontroller through their inter-chip bus, and the sensor takes out the temperature field of the measured environment, and at the same time programs the microcontroller so that the microcontroller can read the temperature data detected by the sensor and process and store the data. The microcontroller is also connected to the PC through the serial communication module at the same time, and then the microcontroller is programmed so that it can transmit the temperature data read from the sensor to the PC, and the PC analyzes, displays and determines whether the alarm is alarmed.

Choice of Thermal Infrared Sensors

After comparing the various infrared array sensors currently on the market, the initial sensors selected are Panasonic AMG8831, Mailex MLX90620, Omron D6T-44L-06, Heimann HTPA8×8. After further comparison, although the temperature measurement range of Myleson MLX90620 is relatively large -20 °C ~ 300 °C, its field of view is 60 ° ×15 °, and the vertical angle of view is too small; the shortcoming of Omron D6T-44L-06 is that its temperature measurement range is -5 °C ~ 50 °C is too small; the price of Heimann HTPA8×8 is too expensive, about two thousand yuan. In addition, many devices are not in stock in China, and they need to be shipped from abroad after purchase, which takes a long time. Therefore, considering time and other factors, the final choice of infrared array sensor in this design is Panasonic AMG8831. The diagram of its substance is shown in Figure 1.

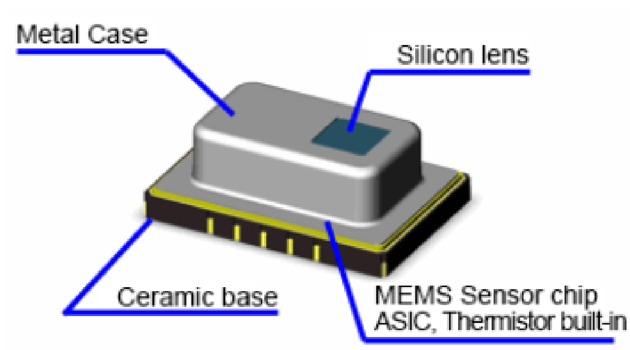

Figure 1: AMG8831 physical drawing

The AMG8831 has a rated operating voltage of 3.3V and pixels of 8×8, and its 1~64 pixels arrangement is shown in Figure 2. The field of view is 60° ×60°, and the external interface is I²C. Its working mode is divided into three modes: normal, sleep and standby, which is very environmentally friendly and energy-saving. Another advantage is that the price is economical. Its operating temperature range and temperature measurement range are 0°C ~ 80 °C, although not very high, but it is enough for us to use it only as an experiment.

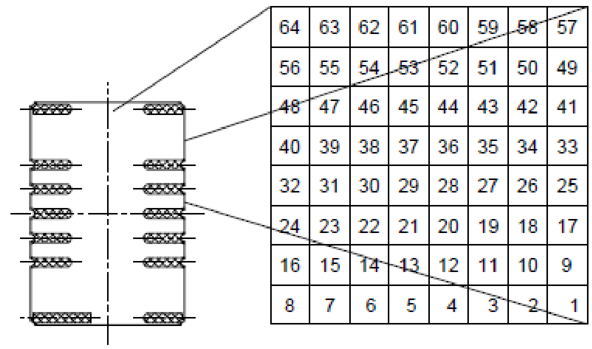

Figure 2: AMG8831 pixel arrangement

Selection of Control Chip

The control chip initially selected by the system is the PIC series of microcontrollers, which are produced by microchip companies in the United States, which is a programmable integrated circuit that can be developed and can control peripheral devices and adopts an embedded microcontroller with RISC structure. PIC series of microcontrollers has the advantages of high execution efficiency, superior development environment, good confidentiality, high speed, and economical price.

This system selects the PIC16F886 in sodic package mode, and its pin diagram is shown in Figure 3.

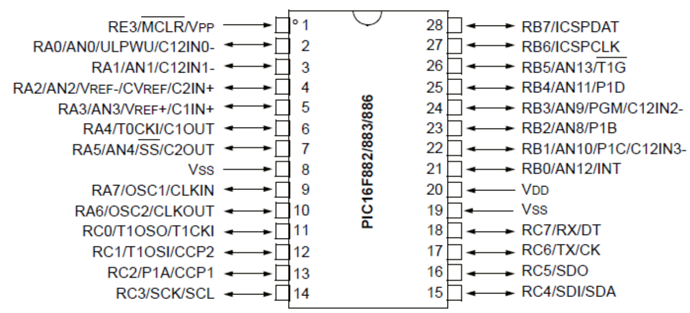

Figure 3: PIC16F886 pin diagram

The Choice of Serial Communication Module

The SP3232EEN chip is a single-supply level shifting chip designed by Sipex for the RS-232 standard serial port, which consists of two drivers, two receivers, and a high efficiency charge pump, meets the TIA/EIA-232-F standard, and provides a circuit interface between an asynchronous communication controller and a serial port connector. A charge pump and four 0.1μF external capacitors allow the chip to operate from 3.0V to 5.5V. It operates at data signal transmission rates up to 235kbit/s and has a maximum driver output slew rate of 30V/μs. These features allow it to fully implement the functionality of RS-232. The pin diagram is shown in Figure 4.

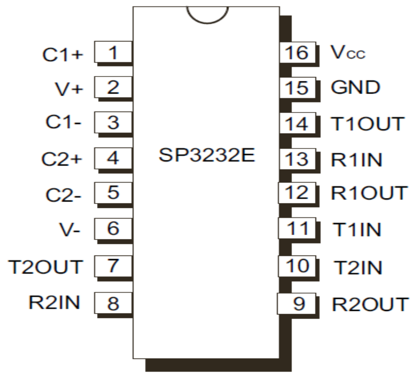

Figure 4: SP3232EEN pin diagram

Selection of Power Supply

Since the infrared array sensor used in this system, the level translation chip for microcontroller and serial port communication can all work at 3.3V voltage, so we choose a 3.3V switching power supply as the power supply.

Hardware Design of The System

Mems Sensor Module

The AMG8831 contains an infrared temperature sensor of 8x8=64 pixels, and the device contains a thermistor to measure the ambient temperature of the device's operation. Its INT terminal is usually high, and it becomes low after an interrupt.

In this system, we use the recommended external circuit of the sensor given by Panasonic officials, choose to set the sensor's I²C slave address to 1101000 and AD_SELECT pin 5 to ground, the external circuit of the sensor is shown in Figure 5.

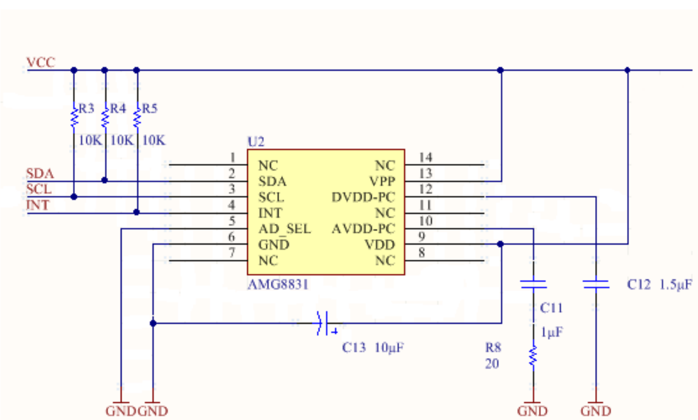

Figure 5: AMG8831 external circuitry

The amg8831 control register includes the following 11 registers:

1. The operating mode register PCTL.
2. Reset register RST.
3. Frame output rate setting register.
4. Interrupt control register INTC.
5. Status register STAT.
6. Status clear register SCLR.
7. Average data register AVE.
8. Interrupt threshold setting register INTL.
9. Thermistor temperature registers TTHL, TTHH.
10. Interrupt bit register INT0-INT7.
11. Infrared temperature measurement temperature registers T10L, T10H.

Microcontroller Module

The main pins used in this system are Pin 1, which is connected to the power-on reset circuit; Pin 2 is used as a general-purpose I/O port, which is connected to the light emitting tube to display the operating status of the system; Pin 3 is used as a general-purpose I/O port, connected to the light emitting tube to display the alarm status of the system; No. 8 and No. 19 are VSS pins, grounded; Pin 14 is used as the input and output port of the clock signal of the I²C bus, which is connected to the SCL pin on the AMG8831 Pin 15 is used as the data signal input and output port on the I²C bus to connect to the SDA pin on the AMG8831; pin 17 is used as the asynchronous serial output port to connect to the TX pin on the SP3232EEN; pin 18 is used as the asynchronous serial input port to the RX pin on the SP3232EEN; VDD pin 20 is used as the VDD pin, It is connected to a 3.3V power supply; pin 21 is used as the interrupt input port of the microcontroller and is connected to the INT interrupt output pin of the infrared array sensor; pin 27 is used as an online serial programming clock port, which is connected to the ICSPCLK pin of the emulator; pin 28 is used as an online serial programming data port, which is connected to the ICSPDAT pin of the emulator. The external circuit of the microcontroller is shown in Figure 6.

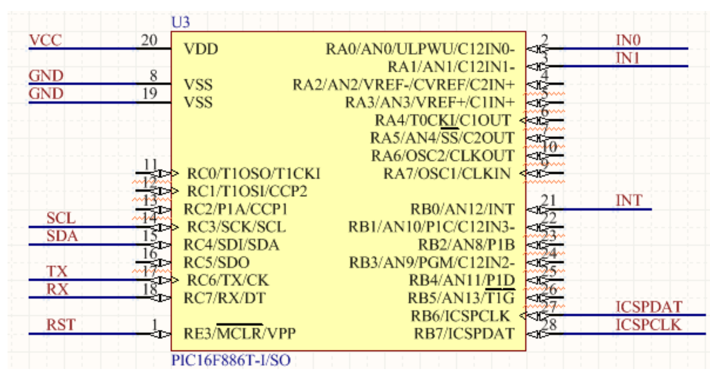

Figure 6: PIC16F886 external circuitry

Serial Communication Module

The level shifting chip selected by the PIC16F886 for communication with the computer is the SP3232EEN chip, through which the data collected by the PIC16F886 is displayed by the PC. The PC receives data using the shared software serial port assistant, and the baud rate of the work is 9600. The serial port assistant only receives display data and does not send data commands to the next bit machine. The pin names of the SP3232EEN are shown in Table 1.

Table 1: SP3232EEN pin name

Pins	name	Pins	name
1	C1+	9	R2OUT
2	V+	10	T2IN
3	C1-	11	T1IN
4	C2+	12	R1OUT
5	C2-	13	R1IN
6	V-	14	T1OUT
7	T2OUT	15	GND
8	R2IN	16	VCC

Design of System Software

Development Environment Based on Mplab Ide Software

MPLAB IDE is a software running on a PC, it is a comprehensive editor, project manager and design platform for microchip PIC series microcontrollers for embedded design application development.Because it provides a single integrated environment to develop program code for embedded microcontrollers, it is called an integrated development environment or IDE. By using the MPLAB IDE and emulator, we can write, edit, debug, and flash program code to a microcontroller that contains all the components needed to design and deploy embedded system applications. The emulator used for debugging and programming is PICKIT3, which connects with the microcontroller through the simulation port, and downloads the code after the compilation link to the microcontroller and can also continuously step forward the simulation.

Program Structure Section

The PIC16F886 serves as the control center, and the AMG8831 is set in a certain operating mode through I²C, and the data such as the temperature status measured in this mode is transmitted to the PC through the SP3232EEN chip. The overall program consists of the minimum system operating mode setting of the PIC16F886 (including the basic configuration setting, the operating frequency setting, the internal clock setting), the setting of the communication interface between the PIC16F886 and the PC, the design of the I²C communication between the PIC16F886 and the AMG8831, the main program design, the alarm program design and other parts. The program is set up via MPLAB IDE, PICKIT3 download programming.

The serial communication program is to transmit the measured data to the PC for display, so that the microcontroller works in asynchronous communication mode. The baud rate of the microcontroller is 9615, and the baud rate of the PC is 9600, and the error is within 0.16%.

The serial port sending data program runs in the main loop, and through the SP3232EEN interface circuit, the parameters such as temperature read out by I²C are transmitted to the serial port assistant of the PC in turn. The PC screen displays the measured data. Serial port sending data program: This part of the program runs in the main loop, through the SP3232EEN interface circuit, the temperature and other parameters read out by I²C are transmitted to the serial port assistant of the PC in turn. The PC screen displays the measured data.

Serial port sending data program: This part of the program runs in the main loop, through the SP3232EEN interface circuit, the temperature and other parameters read out by I²C are transmitted to the serial port assistant of the PC in turn. The PC screen displays the measured data.

```
unsigned char Read_GRID_EYE_Byte(unsigned char addr)
                 {
 // Read write data and commands for address.
              unsigned char   rdata;
              send_start_bit();
     SSPIF = 0;
     SSPBUF =0xD0;
     while(SSPIF ==0);
     SSPIF = 0;
     SSPBUF =addr;
     while(SSPIF ==0);
     send_start_bit();
     SSPIF = 0;
     SSPBUF =0XD1;
     while(SSPIF ==0);
     SSPIF = 0;
     RCEN=1;
     while(RCEN==1);
     rdata=SSPBUF;
     stop_I²C();
     return(rdata);
          }
```

Main programming

This part of the program needs to be completed, the power-on initialization PIC16F886 makes it work, and the open timing interrupt is opened so that it produces a timing flag. The I²C and serial communication programs are then initialized. The large loop uses the timing flag of the timing interrupt to time the infrared test of pixel temperature and serial port communication.

```
main()
      {
  OPTION_SET();
           {
   T0IE = 1;
   IOCB0= 0;

  GIE =  1;
           }
      {
ANSEL  = 0x00;
ANSELH = 0X00;
      }
  TRISB0 =1;
  TRISA0 =0;
```

```
  TRISA1 =0;
  SET_I²C();
  Serial_set();
  Write_grid_eye(0x01,0x3f);
for(SS0=0;SS0<250;SS0++)
            {
NOP();NOP();NOP();NOP();NOP();NOP();NOP();NOP();NOP()
;NOP();
            }
SS0=Number[1];
while(1==1)
     {
if(flag.bt.f2==1 & flag.bt.f4==0)
            {
   RA0=1;
flag.bt.f2=0;   flag.bt.f4=1;
  Serial_out();
     }
if(flag.bt.f2==1 & flag.bt.f4==1)
     {
RA0=0; //RA1=0;
flag.bt.f2=0;   flag.bt.f4=0;
```

Experimental Results and Analysis

The experiment is divided into three parts: the system works at room temperature, the hot water cup is placed in front of the sensor for the experiment, and the Yuba is used in the field of view of the sensor for the experiment. The system has two LEDs to display the operating status of the system, the green LED flash indicates that the system is operating normally, and the red LED lights up to indicate that the measured temperature exceeds the set value and alarms.

When the system works at room temperature, the system runs normally, the green LED flashes and the red LED goes out. When the hot water cup is placed in front of the sensor, the temperature measured by the system exceeds 40℃ and gives an alarm. The green LED flashes and the red LED lights up. When the lamp is used to warm the sensor's field of view, the temperature measured by the system exceeds 40℃ and gives an alarm. The green LED flashes and the red LED lights up.

Conclusion

In summary, the hardware circuit and software program designed in this design can initially meet the technical requirements of infrared temperature measurement and confirm the feasibility of its application to fire detection in large space places.

The infrared sensor AMG8831 selected for this study also has the function of displaying the detected data as a thermal image, which we did not use in this experiment, but it is also very useful when applied to actual fire detection in the future, which can make the system function more perfect.

References

1. Buchanan, A. H., & Abu, A. K. (2017). Structural design for fire safety. John Wiley & Sons.
2. Kim, J., Shan, Y., Kim, S., Song, D., Park, H., & Bang, C. (2021). Factors Influencing Fire Safety on Building Construction Sites: A Fire Officer's Perspective. Journal of Construction Engineering and Management, 147(10), 04021118.
3. Dougherty, E. R. (2020). Digital image processing methods. CRC Press.
4. Burnett, J. D., & Wing, M. G. (2018). A low-cost near-infrared digital camera for fire detection and monitoring. International journal of remote sensing, 39(3), 741-753.
5. Wang, J., Roudini, S., Hyer, E. J., Xu, X., Zhou, M., Garcia, L. C., ... & Da Silva, A. M. (2020). Detecting nighttime fire combustion phase by hybrid application of visible and infrared radiation from Suomi NPP VIIRS. Remote sensing of environment, 237, 111466.
6. Prasojo, I., Nguyen, P. T., & Shahu, N. (2020). Design of Ultrasonic Sensor and Ultraviolet Sensor Implemented on a Fire Fighter Robot Using AT89S52. Journal of Robotics and Control (JRC), 1(2), 55-58.
7. Abdulsahib, G. M., & Khalaf, O. I. (2018). An improved algorithm to fire detection in forest by using wireless sensor networks. International Journal of Civil Engineering & Technology (IJCIET)-Scopus Indexed, 9(11), 369-377.
8. Fonollosa, J., Solórzano, A., & Marco, S. (2018). Chemical sensor systems and associated algorithms for fire detection: A review. Sensors, 18(2), 553.
9. McCarley, T. R., Smith, A. M., Kolden, C. A., & Kreitler, J. (2018). Evaluating the Mid-Infrared Bi-spectral Index for improved assessment of low-severity fire effects in a conifer forest. International Journal of Wildland Fire, 27(6), 407-412.