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# *Research on the Design of Intelligent Human Body Position Detection and Tracking System*

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***Abstract:*** In this paper, an intelligent human body detection and tracking system based on Sunplus 16-bit single-chip microcomputer is designed. This system uses the Sunplus 16-bit single-chip microcomputer SPCE061A as the control unit, and the human body infrared pyroelectric sensor as the sensing element to perceive the position information of the surrounding human body and transmit it to the single-chip microcomputer, and then control the operation of the stepping motor to realize the functions of human body position detection and tracking. The system is set with three working modes, namely automatic, manual and voice control, making the control more convenient and flexible. The sensors are arranged in an octagonal impeller structure, which effectively reduces the sensing blind spots of the sensors, thereby improving the stability and reliability of the system's operation. Through testing, the system operates stably and reliably, has good tracking performance and has no sensing blind spots.

## 1. Introduction

Since the concept of the Internet of Things was put forward, it has received extensive attention from all walks of life, and remarkable progress has been made in the research on Internet of Things technologies. At present, the applications of the Internet of Things are mainly concentrated in the following six major fields: smart home, smart agriculture, intelligent transportation, smart grid, smart medical care, environmental monitoring, and so on. With the improvement of people's living standards and the level of science and technology, creating a high-quality intelligent living and home environment has become an urgent need for modern people. With the help of the Internet of Things, our lives can be made easier and more pleasant. The purpose of a smart home is to enable all electrical appliances to sense changes in the surrounding environment and the needs of the owners and to work according to requirements.

Small household appliances such as small fans and electric heaters have entered thousands of households. In addition to having the general functions of blowing air and providing heat, these small appliances usually have a swinging head function to work in different directions. However, in practical applications, when the positions of one or more people change, the working direction of small appliances can only be adjusted manually. Moreover, the working range is limited and they cannot work in a 360-degree range, resulting in inconvenience in the use of small appliances, low efficiency, and high energy consumption. Therefore, there is an urgent need for an intelligent human body detection and tracking device with the function of detecting and tracking human body positions.

In nature, any object with a temperature higher than absolute zero is constantly emitting infrared radiation into the surrounding space [1, 2]. The higher the temperature of an object is, the shorter the peak wavelength of its radiated thermal energy will be. According to experiments, the infrared wavelength radiated by the human body with a temperature between 36 ℃ and 37 ℃ is about 9 μm-10 μm [3, 4]. Many sensors based on infrared technology on the market at present can detect electromagnetic waves with a wavelength of 6 - 14 μm radiated by the human body. When someone moves within the detection area, the radiated infrared rays are focused by the Fresnel lens onto the pyroelectric sensor[5]. This paper designs an intelligent human body detection and tracking system that can automatically detect human body positions within a 360 ° range and can automatically track them. In addition to having the basic functions of manual adjustment and automatic adjustment of the direction, this system also has a voice control function.

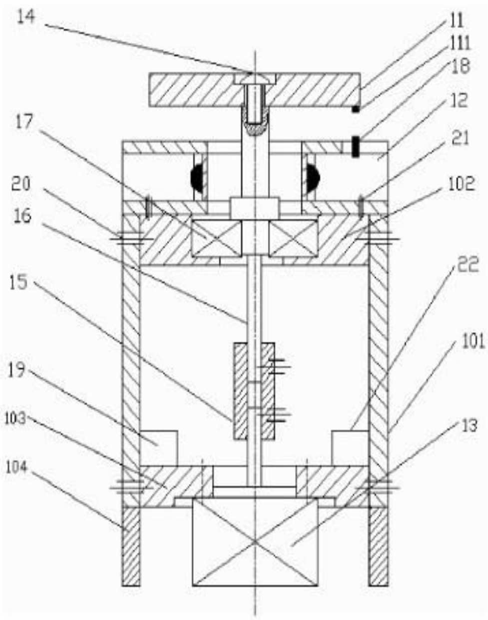
## 2. System Working Principle

All objects existing in nature, such as the human body, ice cubes, etc., as long as their absolute temperature is higher than -273℃, will emit infrared rays outward, only with different wavelengths of the infrared rays they radiate. And the infrared detectors based on the pyroelectric effect detect the human body by using the infrared rays radiated by the human body. The higher the temperature of an object is, the shorter the peak wavelength of its radiated thermal energy will be. According to experiments, the infrared wavelength radiated by the human body with a temperature between 36℃ and 37℃ is about 900 - 1,000 nm. Based on the pyroelectric effect and the particularity of the infrared wavelength radiated by the human body, as long as other unwanted light waves are removed, the purpose of detecting the human body can be achieved.

The pyroelectric effect refers to the change that occurs on the surface of some ferroelectric substances. As the temperature rises or falls, a change in electric charge will occur on the surface of these substances [6]. The infrared human body detection sensor based on the pyroelectric effect is selected in this design.

## 3. Overall Design

This design consists of a sensor assembly, a single-chip microcomputer control unit, an infrared human body detection module, a stepping motor control module, a voice control module, a photoelectric switch, as well as a liquid crystal display and a keyboard module, as shown in Figure 1. The system is designed with three independent keys, corresponding to three different working modes, namely automatic, manual and voice control respectively. When Key 1 is pressed, the system operates in the automatic mode. The sensors automatically detect the position of the human body, and the stepping motor automatically rotates in a loop in the area where there is a signal. When Key 2 is pressed, the system operates in the manual mode. Users can manually adjust the rotation path of the stepping motor according to actual needs. When Key 3 is pressed, the system operates in the voice control mode. Users can use voice to control the system, making the stepping motor rotate, start and stop within an appropriate range.




11 Turntable
12 Sensor Mounting Assembly
13 Stepping Motor
15 Coupling
17 Support Bearing
18 Photoelectric Switch
19 Stepping Motor Driver
22 Single-chip Microcomputer Controller
101 Side Plate
102 Cover Plate
103 Bottom Plate

Figure 1: Schematic Diagram of the Device Structure

## 4. Hardware Circuit Design

In this design, the Sunplus 16-bit single-chip microcomputer SPCE061A is used as the control unit, the human body infrared pyroelectric sensor is adopted as the sensing element, and the stepping motor serves as the execution unit. Meanwhile, the Sunplus module SPLC501 is utilized to display the human body position information in real time, so as to realize the detection and timely tracking of human body positions.

## 4.1. Introduction to the "61" Board

The "61" board is the abbreviation of SPCE061A EMU BOARD. It is a simplified development and simulation experiment board with the Sunplus 16-bit single-chip microcomputer SPCE061A as the core. Besides having the minimum system circuit of the single-chip microcomputer, the "61" board also includes an active circuit, an audio circuit (including the MIC input part and the DAC audio output part), a reset circuit, etc. It is powered by batteries and is convenient to carry around. The schematic diagram of its hardware structure is shown in Figure 2 [4]. The ports of the "61" board are simply and reasonably arranged, and the voice module has been integrated, which can easily perform functions such as language output and voice recognition. Therefore, the "61" board is selected as the control board in this design.

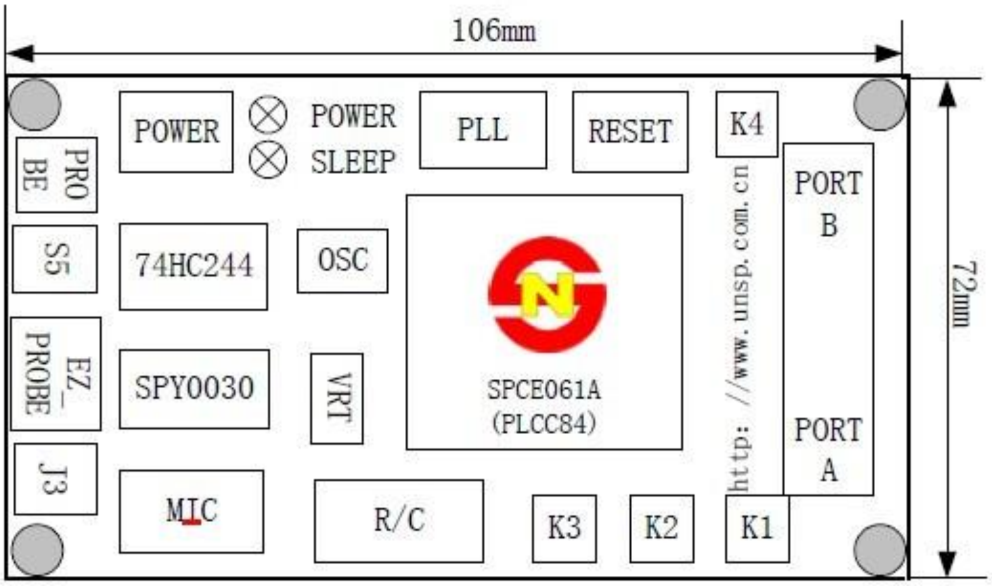



Figure 2: Schematic Diagram of the Hardware Structure of the "61" Board

## 4.2. Infrared Human Body Detection Part

In this design, the sensor module HC-SR501 integrated with the human body infrared pyroelectric sensor LHI778 is selected as the sensing element to detect the specific position information of the human body. The HC-SR501 human body induction module has the advantages of high sensitivity, strong reliability and low power consumption, and is widely used in various types of automatic induction electrical equipment. This module adopts fully automatic induction. When a person enters its sensing range, it outputs a high level. When a person leaves the sensing range, it automatically delays and turns off the high level and outputs a low level.

What this design aims to achieve is human body detection within a 360-degree range. In order to minimize the sensing blind spots as much as possible and make full use of each sensor, the octagonal impeller structure designed in the utility model patent with the application number of 201120504578.2 is adopted in this design[5]. The octagonal impeller structure means that eight infrared human body sensors are respectively arranged at the middle positions of the eight sides of a regular octagon, as shown in Figure 3. The sensors output level signals which can be directly sent to the single-chip microcomputer for processing. In this design, the signal output terminals of the eight sensors correspond to the IOA8 - IOA15 ports of the single-chip microcomputer respectively.

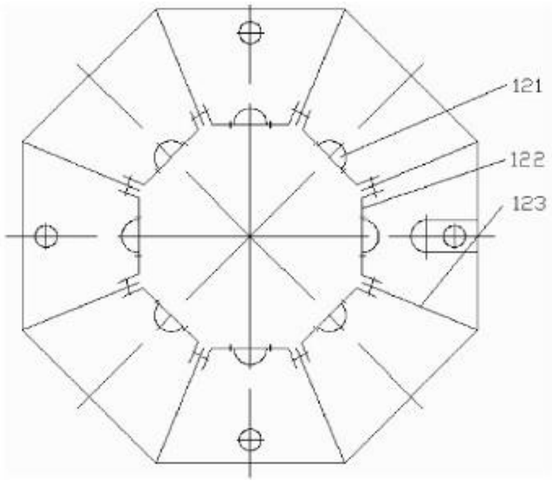



Figure 3: Schematic Diagram of the Octagonal Impeller Structure

### 4.3. Stepping Motor Control Part

In this design, a stepping motor with the model number of 57BYGH51-402A and a step angle of 1.8 ° is selected. For the stepping motor drive circuit, a drive module integrated with the drive chip Toshiba TB6560AHQ is chosen to drive the stepping motor. The driver circuit adopts a common anode connection method. The VC terminal is connected to a 5V power supply, the stepping pulse terminal CLK is connected to the IOB0 port, the direction terminal DIR is connected to the IOB8 port, and the enable terminal EN is left floating.

### 4.4. Display Circuit

The display part of this design selects the SPLC501 module of Sunplus Company. The SPLC501 module is a liquid crystal display with a 128×64 dot matrix, which can display characters, Chinese characters and graphics, etc. In this design, the contents that need to be displayed mainly include the display of the position and direction of the human body, the status of the system's working mode, as well as the electronic clock.

### 4.5. Voice Recognition Circuit

The SPCE061A is a 16-bit single-chip microcomputer with DSP functions and has a strong information processing capability. Its maximum clock frequency can reach 49 MHz, possessing the advantage of high computing speed. All these undoubtedly provide conditions for voice playback, recording and playback, synthesis and recognition[6]. The "61" board takes the SPCE061A single-chip microcomputer as the core processing element and has powerful voice processing functions. As shown in Figure 4, X1 is the MIC input terminal for voice, which comes with automatic gain control (AGC). J3 is the voice output interface, a 2-pin external speaker. The output from the DAC output pins 21 or 22 is amplified by the voice integrated amplifier SPY0030A and then output. The SPY0030A is a chip of Sunplus. Its function is equivalent to that of the LM386, but it has better sound quality than the LM386. It can work within the range of 2.4 - 6.0 V, and the maximum output power can reach 700 mW. Besides the basic functions of voice storage and playback, the Sunplus single-chip microcomputer integrated in the "61" board also has the function of voice recognition.

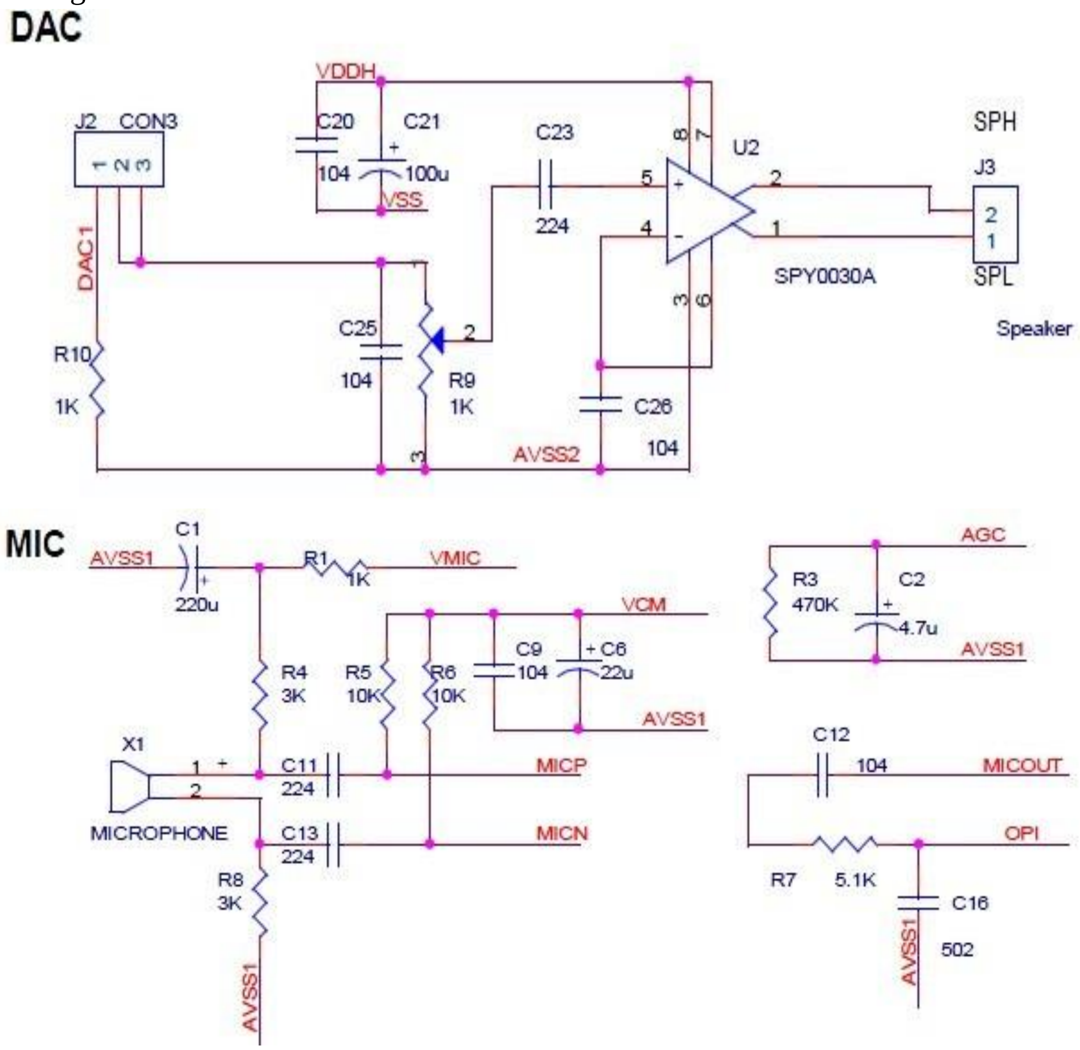



Figure 4: Sunplus Audio Circuit Diagram

## 5. Software Program Design

### 5.1. Introduction to Programming for the Sunplus 61 Single-Chip Microcomputer

Since the "61" board with the SPCE061A single-chip microcomputer as the core is used, the peripheral circuits have become very simple. The writing and debugging of all the system programs are completed in the integrated development environment u'nSP IDE which is dedicated to the Sunplus single-chip microcomputer.

In this design, the method of combined programming using the C language and the assembly language is adopted. The C language is used for programming the main program and calling other program modules, which can make full use of the advantages of the C language. The assembly language is mainly used in the subroutine modules, taking advantage of its merits in interrupts and delays.

The system software adopts a modular program structure. The program modules include the initialization and main program, key program subroutines, LCD liquid crystal display subroutines, stepping motor control subroutines, voice control subroutines, photoelectric switch reset subroutines, and so on.

## 5.2. Main Program

The main program is written in the C language. It is the core of a program and is compiled according to the overall design requirements. The main program mainly includes system parameter settings, device initialization, and the calling of various subroutines.

## 5.3. Infrared Human Body Detection Subroutine

The detection of human body positions is one of the main purposes of this design. The writing of the human body position detection subroutine is the key to whether the functions of the entire system can be realized. In this design, eight sensor modules are used and are respectively input into eight I/O ports of the single-chip microcomputer. In the program design, an array n[k] is defined to record the sensor signal information. The details are as follows: The eight sensors are numbered 0, 1, 2, 3, 4, 5, 6, and 7 respectively. When the No. 0 sensor has a signal output, the variable k is incremented by 1, and the array element n[0] = 0; when the No. 1 sensor has a signal output, the variable k is incremented by 1, and the array element n[1] = 1, and so on. The variable k records the number of sensors with signal output, and the array n[k] records the numbers of the sensors with signal output.

## 5.4. Stepping Motor Control Subroutine

The stepping motor is the actuating element of the system. After the sensor signals are transmitted to the single-chip microcomputer, the single-chip microcomputer performs calculations to obtain the number of steps for the stepping motor to execute. The angle Y corresponding to each sensor is $Y = i * 45°$, and the number of steps s of the stepping motor is $s = Y / 1.8$. Then the number of steps is sent to the stepping motor to make it rotate to the position where people appear and cycle within the area where there is a signal.

## 5.5. Voice Recognition Subroutine

The voice control mode of this design is mainly based on the Sunplus audio functions. The "61" board can play, record and synthesize voices, with the corresponding compression algorithms SACM_A2000, SACM_S480, SACM_S240, and MS01 respectively. In addition, the "61" board also has the function of voice recognition. Voice recognition is mainly divided into specific speaker recognition (SD) and non-specific speaker recognition (SI). The voice control function that this design is required to achieve is the recognition of specific speakers.

In the program, the recognition of continuous sounds of specific speakers is demonstrated through the training of three statements, among which the first statement is the trigger command. At the beginning of the program, the trigger command is trained first, and then it prompts to train two commands. After the training is completed, voice recognition begins. When the trigger name is recognized and a command is issued, a response will be heard. The specific commands are as follows:

********** Training **********

| Prompt Sound | Input Voice |
| --- | --- |
| "Please enter the trigger name" | "Hello" |
| "Please enter the first command" | "Open" |
| "Please enter the second command" | "Close" |

"Please say it again" (This command appears after each prompt sound is finished.)

"No sound detected" (This command appears when no sound is detected.)

"Two input names are not the same" (This command appears when the two input names are different.)

"Two input commands are not the same" (This command appears when the two input commands are different.)

"Ready, please start recognition" (When all three statements are successfully trained, enter the recognition stage.)

****************** Recognition **********************

| Issue Command | Response |
| --- | --- |
| "Hello" | "Hello, master" |
| "Open" | "Okay, master" |
| "Close" | "Okay, master" |

Note: Enter the command 2 - 3 seconds after each prompt sound ends or issue a command 2 - 3 seconds after the previous response ends.

## 6. Online Debugging

The hardware circuit of the system has been connected, and the software program has also been written. After carefully checking the hardware wiring of the system and confirming that there are no errors, online debugging can be carried out. The joint debugging of software and hardware is also carried out in modules. In this design, the debugging of modules such as human body position detection, liquid crystal display, stepping motor control, and voice recognition was carried out successively. After solving the problems that occurred in each module, the overall system debugging was then carried out. During the overall debugging process, since the voice recognition process takes a certain amount of time, it is necessary to delay for 2 - 3 seconds after the single-chip microcomputer responds before issuing the next command. Moreover, the sensing range of the infrared human body sensor is limited. When the human body is more than 5 meters away from the system device, the sensor's sensing will become less sensitive.

## 7. Conclusion

An intelligent human body detection and tracking system based on the Sunplus 16-bit single-chip microcomputer was designed. In this system, the Sunplus 16-bit single-chip microcomputer is used as the control unit. The human body infrared pyroelectric sensor is used to sense the human body position information around the device. After being processed by the single-chip microcomputer, the stepping motor is driven to operate to realize the human body tracking function. The sensor layout of the system adopts an octagonal impeller structure, which effectively eliminates the sensing blind spots of the sensors and improves the reliability and stability of the system's operation. In addition, this system is equipped with three working modes, namely manual, automatic and voice control, making the control more convenient and quick.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## References


*[1] Yao Jinsheng, Li Kailong, Liu Dongya. Lifestyle Based on the Internet of Things [J]. Science and Technology Innovation Herald, 2012, 25: 23.*

*[2] Gu Fangjie, Fang Hong. Infrared Human Body Detection Based on Pyroelectric Effect [J]. Electronics World, 2012, 07: 48.*

*[3] Jin Huiqing. Principle and Application of Pyroelectric Infrared Sensor [J]. Coal Technology, 2008, 27(8).*

*[4] Sunplus Technology University Program. 61 Board User Manual: 1.*

*[5] Chen Honglei, Zhang Xiliang, et al. A Human Body Position Detection and Tracking Device [P], Instruction Manual: 3. 2012.*

*[6] Hou Yuanbin, Yuan Yimin, Huo Hanping, et al. Principles of Sunplus Single-Chip Microcomputer and Selected Graduation Design Projects [M]. Science Press, 2006: 144.*