Design of automatic door controller based on infrared sensor array

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Abstract

The automatic door controller is based on Freescale S9S12G128 microcontroller core. Light-emitting diodes and photosensitive diodes make up sensor array with peak wavelength of 940 nm and in active infrared pattern, transmitting modulated infrared light diffuse reflection. Signals are processed by optical lens and comparing the result with the threshold values, which judged existence, location, speed, direction of moving (static) people (object) in front of door to realize automatic switch control of door. The experiments show that automatic door controller with small size, low cost, has approaching use, high sensitivity, low rate of false negatives and omission characteristics and has a good practical value and application prospects.

Keywords

Active Infrared; Existence and position detection; Sensor array; Controller.

1. Introduction

With the progress of social and development of economy, the automatic door be used widely in airports, banks, shopping malls, hospitals, hotels, office buildings etc..The controller is the core of the automatic door system, which is one of the most important indicators of its conceptual and manufacturing levels[1]. The existing controller mainly detects by infrared technology, radar technology as the core, and the controller infrared technology is divided into active and positive parts. Active infrared controller refers to ones who itself has the function of transmitting and receiving infrared according to the change of the transmitting and receiving infrared to judge the result[2]; This article which aims to design a small volume, low cost, high sensitivity, omission and lower false rate, uses light with the peak wavelength of 940 nm to emit diode and photodiode sensor array by active infrared mode more near controller using the automatic door controller to detect someone (static) or something moving in front of door, whose position, movement speed with its direction ,and automatic door switch signals are given.

2. System Design

2.1 Composition of System and Working Principle

System is mainly composed of Freescale S9S12G128 single-chip microcomputer, optical lens, power supply module, launch infrared photodiode array module, the infrared photosensitive diode array module, execution unit, the light-emitting diodes led directives and infrared remote control unit, etc. The system hardware composition block diagram is shown in fig.1. The single chip microcomputer is the control core of the system and infrared photodiode array module, which transmits infrared intensity modulation. Infrared photodiode array module receives the infrared light to deal with it and gives the door switch signal by executing unit .The infrared remote control unit can be necessary to set parameters of the controller, and light emitting diode is used to display the working state of the controller and remote control set.

Detecting principle for someone or something is to intensity modulate infrared radiation toward someone or something till diffusing reflection occurs, and via the optical lens received by infrared

photosensitive diode with the signal amplification and processing to receive the changing condition of infrared light.

After installing the system, when no one or nothing under the controller start to initialize the controller. Under the influence of the ambient light and diffusing back to the ground, infrared receiving array

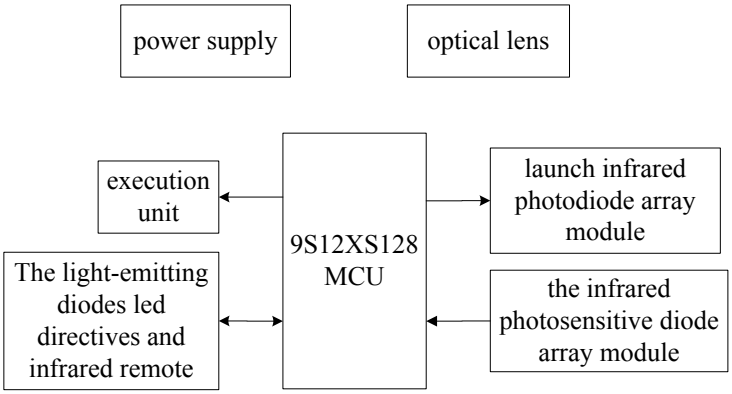


Fig.1 System Block Diagram

module receives the infrared radiation intensity for V_s; when there is someone, something or other influence, infrared receiving array module receives the infrared radiation intensity for V_c. Where system works and sets the threshold for V_0, when the infrared light intensity changes value, which is $|V_c - V_s|$,is equal to or greater than the threshold V_0,and execution units give the open signal; when the infrared light intensity changes value, which is $|V_c - V_s|$,lower than the threshold, and execution units give the close signal. Opening and closing conditions can use formula expressed as equation (1) and equation (2).

$$|V_c - V_s| \geq V_0 \tag{1}$$

$$|V_c - V_s| < V_0 \tag{2}$$

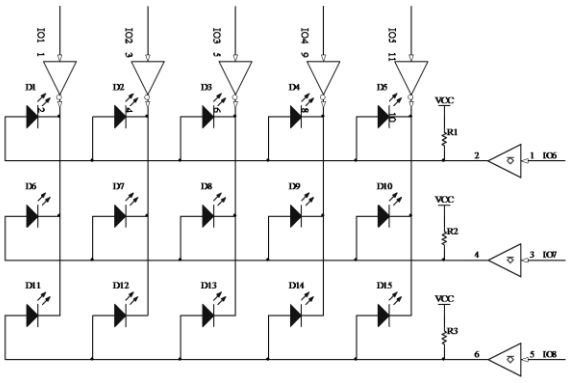


Fig.2 Launch Array Module Diagram

2.2 Sensor Array Design

Transmitting array and receiving array is composed of peak wavelength of 940 nm optoelectronic components, which consisted of 15 photoelectric element structures for the square 3 line 5 array columns respectively. In order to meet requirements of systems' size, optoelectronic devices used SMD encapsulation: Leds light's company is Taiwan IR91-21 c/TR10, which launches infrared peak wavelength of 940 nm, and firing Angle is 25 degrees; Photosensitive diode's company is Vishay VEMD2000X01, which spectral band range is between 750 nm to 1050 nm. The sensitive peak wavelength is of 940 nm. The response time is of 100 ns. Typical dark current is 1 nA.

Launch Module Design

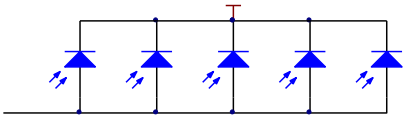
Launch array module design is shown in fig.2. They are composed by a total of 15 leds of three lines of five columns, and their column driving device is ULN2003, and line driving device is FDC6306P. ULN2003 is high withstand voltage with large current composite transistor array, which is made up of

seven compound NPN transistors.FDC6306P is dual p-channel MOS field effect tube, which is the 2.5 V special MOS field effect tube by PowerTrench craft manufactures from Fairchild company. If its grid in 3nC low open is under the premise of rechargeable battery, it can get as low as 0.16 ohms on resistance in which has good switching performance, and is suitable for load switch application. It can meet the demands that emission array only has an infrared light-emitting diode light at a moment , and makes 15 leds for a light emitting diode in turn by column and line driving device signal combination for the launch is a frequency modulation signal intensity, and light frequency can be set.

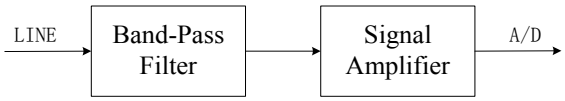
2) Receiving Module Design

Receiving array module is composed of 3 line and 5 columns, including 15 of photosensitive diode, in order to improve the sensitivity of the system, and each output connects to the conditioning signal circuit together, which is shown in fig3. Fig.3: the three lines in the connection mode, the other two lines is connected to the same way.

Fig.3 (b) is conditioning signal circuit diagram, which is one of three roads .The other two way connect to the same way. When receiving arrays receives any faint diffusing infrared light of a photodiode, the infrared light intensity receives through conditioning signal circuit. The Band-pass filter and signal amplifier are realized by the integrated circuit device of TS462.



(a) Line of Photosensitive Element Circuit Connection



(b) Signal Conditioning Circuit Diagram

Fig.3 Receiving module block Diagram

2.3 Performing Unit Design

Execution unit is mainly composed of relay, the control signals of the single chip microcomputer actions relayed by ULN2003 drivers. Relay action is provided for door switch input signal. The relay coil power supply is 7.5 V which produced by LM2574-ADJ.

2.4 Power Supply Design

System as the input is voltage of 3.5 V - 40 V AC or DC. Power-hungry devices is 5 V and 7.5 V power supply. Through the LM2574 – ADJ, it transforms the input voltage to 7.5 V (DC) and provides power supply for execution units and 5 V switching power supply chip. Two pieces of LM1117 5.0 is designed to provide 5V power supply system. Specific schemes for: providing power supply for launch infrared photodiode array module, light-emitting diodes (leds) directives and infrared remote control unit, microcontroller unit by a LM1117 5.0 power supply and Infrared photodiode array module by a LM1117 5.0 which is for the receiving module of small signal processing, which needs stability, small interferences of power supply.

2.5 Light Emitting Diode Directives and Infrared Remote Control Unit

Light-emitting diodes (leds) are used to indicate the working state of the controller with red, green double colors. When working normally, green led lights, when fault occurs, the red led lights .Choosing infrared remote control receiving module by the company Vishay TSOP1838, the

modulation frequency and threshold of remote control set controller of infrared light-emitting diode and so on. Representing different sets of parameters through different color leds flicker frequency changes.

3. The Design of System Software

3.1 Intensity Modulation and Anti- jamming of Emission Light

At a certain time only one LED shines, and the LED's luminous frequency of controller which uses the encoding modulation and synchronous communication technology is fixed. The receiving array module only identify the infrared beam which is strictly synchronized and of which the modulation frequency is fixed.AS for the infrared beams which are not synchronous or not corresponded with the agreed frequency, the receiving array do not identify them, which really avoid the interference of several automatic door controllers when being applied closely. Consequently, only when the approaching automatic controllers are set at different working frequencies, they will not interfere each other, which avert the malfunction of the doors.

3.2 An Introduction of Related Algorithm

In the detecting area, for example, the infrared light emitting array i×j (i=1~3, j=1~5),then the LED at row i and column j is marked as A_{ij}. Under the affect of driving circuit and optical system, when the infrared emitting components are all luminous, of which the infrared light spots presented on the ground are shown by fig4:

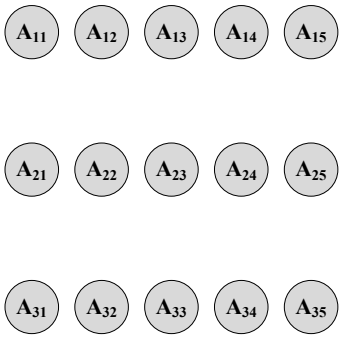


Fig.4 The sketch map of optical projection

The Detection of Existence and Location

In application, the modulated light at fixed frequency is emitted by emitting array module. If there is someone or something at position A_{35}, meanwhile the LED at position A_{11} emit lights, as a result ,the receiving of light intensity diffuse reflected by the array is slightly varied, which is satisfied with expression (2).However, consider the movement of humanity and object is too slow compared with the modulation luminescence, when the position of A_{35} emit lights, because of the existence of people or object, the light intensity largely varies after being diffuse reflected when it is detected by the photosensitive LED of the receiving array, which satisfies expression (1) and can be affirmed the existence of people or objects.

The Detection of Moving Velocity and Direction

When someone or something moves to a approaching location A_{24} (or A_{25}, A_{34}） from A_{35},according to the principle of the detection of existence and location, the changes of people or objects' position can be detected by the receiving array module. Because the installation position of space is fixed, then the distance between A_{35} and A_{24} (or A_{25}, A_{34}） is already known, and the time during the position change period can be calculated, also as a result the velocity can be derived by using displacement and time. Similarly, whether the moving direction of people or objects is along the row or column can be detected. When the moving direction of people or objects is along row, rather than column, it can be considered that people or objects is to pass beside the door rather than through it.

3.3 The Design of Software

The detection software process of the system which for the movement of the open and close of door is shown in fig5..

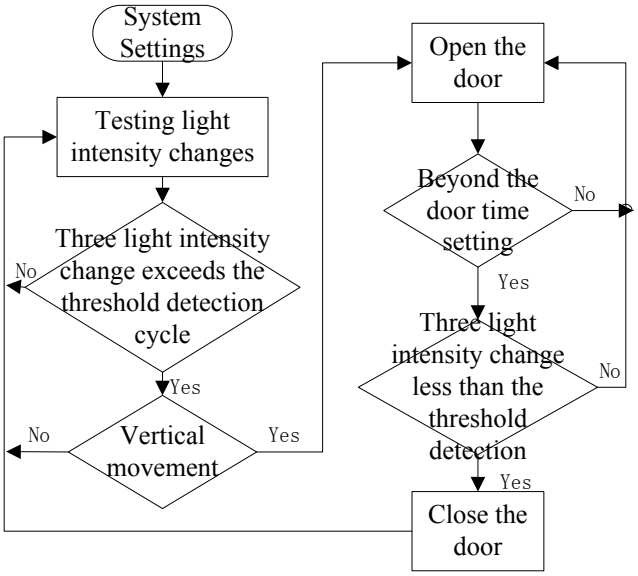


Fig.5 open closed software flow chart

4. The Set of Door Hreshold with Method and experiment

Omission should have acted and false report should not have acted [3] for microwave, ultrasonic, infrared detectors.Through the experiment to study the relationship between the threshold omission and misre for the design of the automatic door controller.

Light signal is converted to a voltage signal by photosensitive diode and after filtering,enlarging the voltage value to compare with the setting threshold,which to judge the door switch. In practice, in order to avoid false report, judging a real relationship with the threshold method and light signal by several comparing and decision process is: when the test results meet the equation 1 (equation 2),and in the next two test period to judge whether the light signal changes also meet the equation 1 (equation 2), if three consecutive detected signal changes meet the equation 1 (equation 2), there needs to open (close) the door,or not open (close) the door.

Even thought do with the algorithm, however, in practice, omission and misrepresentation may still exist if without a proper threshold V_0, Controller is installed on the door, which is 2m high from the ground.Infrared light is perpendicular to the ground,and the projection of infrared light on the ground with the range of 1.2 m * 1.2 m by using infrared receiver test . The ratio of Internal controller noise V_0 and door threshold V_n which is V_0/V_n decides false rate of system. Setting V_n is white noise, signal period is 0.4 ms,and in a certain time interval,the rate of no false report and its corresponding V_0/V_n relationship are shown in table 1. The relation of detection probability P_0 and V_0/V_n are shown in table 2.

Table 1 the relationship of the time of interval false report rate and the ratio of threshold noise V0/Vn

Time interval	1h	8h	24h	2400h
The rate of false P_f	7×10^{-7}	8.6×10^{-8}	2.15×10^{-8}	2.15×10^{-10}
V_0/V_n	4.82	5.23	5.48	6.25

Table 2 the relationship of detection probability P0 and V0/Vn

Detection probability P_0	0.9	0.95	0.97	0.98	0.99	0.999
V_0/V_n	1.29	1.65	1.88	2.06	2.33	3.1

In the experiment, which action selection of threshold method is $V_0=3.1\times V_n$, the detection probability is to 99.9%.The probability of false report, omission are 0.1%.During the test, the test time is 240 hours, misrepresentation, omission didn't happen. In close to use experiments, testing the signal cycle in two different frequency modulation controller which is 0.4 ms and 0.37 ms in close to the two door, no misstatement cases in 120 hours.

5. Conclusion

The automatic door controller using cost-effective microcontroller S9S12G128 to design infrared sensor array and the necessary peripheral circuit. The experiment proved that in the cases of installation height of 2m, and the controller detection range is 1.2×1.2 m, and when the threshold method is $V_0=3.1\times V_n$, the detection probability is 99.9%, and false report, omission probability is 0.1%. Automatic door controller shows capability of stable performance, high detection accuracy, low rate of false report, omission , strong anti-jamming.It meets actual application standard . In addition, the controller has practicability of simple structure, small volume, low cost, strong, etc.Based on this system, it can improve the luminous intensity, optical system, the size of the array,and research automatic door controller with more large detection range, more higher installation height and more widely applications.

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