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Alarm system design of young children being left on school bus based on pressure sensor array

Yongjun Liu[1,*], Hua Peng[2]

[1]School of intelligent manufacturing, Huanghuai University, Zhumadian, China
[2]Library of Huanghuai University, Zhumadian, China

*Corresponding author e-mail: chengquan33@126.com

Abstract. One detecting method for young child being left on school bus based on the FSR (Force Sensing Resistor) sensor array was put forward and the alarm system was designed, which aimed at the frequent occurrence of safety accidents of young children being left on school bus in summer. Four square or circular FSR sensors were combined parallel together and placed on one seat of school bus as one module. Two strip shape FSR sensors were combined parallel together and placed on the ground between seats and on the aisle of school bus as one module. A certain number of modules placed on seats or aisle were combined parallel together and then connected with one input terminal of microcontroller. The resistance of each FSR module is inversely proportional to the pressure being applied. So, whether the young children were left on school bus alone or not can be detected by the resistance of the FSR module. To protect the FSR sensors were not damaged, the FSR sensors were wrapped in two soft silicone cushions. When the young children being left on the school bus alone was detected, the microcontroller would drive the speaker to play the alarm voice for warning the people nearby the school bus to recuse. The FSR sensors could detect the left child on the school bus accurately and the alarm system can warn timely. The detection method and the alarm system can be used for young children school bus to improving the safety of children riding.

1. Introduction

Young children death accidents of being left on school bus alone were occurred every summer. However, the safety regulations of school bus has been promulgated, the technical conditions of school bus and the quality of accompanying teachers on school bus are specified in detail, such accidents still happen frequently due to inadequate supervision and personnel misconduct. The main reason for young children being left on school bus is that the children are asleep on school bus, or some children are naughty and deliberately stay in the car. Because the children are very young, once they are left on school bus alone, they will be at a loss when the door closes. When the temperature inside school bus rises, the children will be injured or die from high temperature and organ failure.

From a technical point of view, the key issue in solving the accident caused by leaving the young child on school bus alone is how to detect the child left in the school bus. Scholars and technicians have also extensively studied the technical prevention method of school bus accidents. Li, Ma and Deng proposed using the PIR (Passive Infrared Radiation) sensor and relevant algorithms to detect the human body on school bus[1-3]. The method is effective for detection of moving human body and if the children are asleep on school bus, which will be inoperative. Li used the piezoelectric sensor which is

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amounted on the entry pedal of school bus to detect the amount of students on board and off the bus to determine whether the children are left on school bus alone[4]. If two children get on school bus together or the children jump off school bus, the counting result will be wrong. Wu and Liu proposed using the RFID (Radio Frequency Identification) card to detect the on board or off school bus. The students are demanded to carry the RFID card and must swing RFID card when they get on and get off school bus. It is excessive for students, especially for young preschool age children. If the students forget to bring their RFID card or forget to swing their card when they get on or off the bus, the detection result will not accurate[5-6]. Image and video are the research hotspots for human body detection[7]. Wu[8], Wu[9] and Shayhan[10]proposed using the machine vision to detect the quantity of students on school bus. The algorithm needs excellent algorithm and it still has a certain missing detection rate. Zhou[11] proposed using the RFID card and machine vision together to detect the being left on school bus students and there still has some shortcomings of forgetting to bring card and missed detection rate. If the left student is missed detection, the accident of injury or death may occur.

The critical of preventing the accidents of young children being left on school bus alone is human body detection. There is a possibility of missed detection of PIR, FRID or machine vision. FSR sensors array is proposed for reliable detection of young children being left on school bus alone. The FSR sensors are placed on the seats, on the ground between seats, and on the aisle in this article. The resistance of FSR sensors will drop substantially when the child is pressed on the sensors at any position, so that detecting the resistance of FSR sensors can analyze whether the children are left on school bus alone or not. If the children are left on school bus, the microcontroller will drive the speaker to play the alarm voice for warning the people nearby the school bus to recuse, which can improve the safety of children riding.

2. General design

The system general design is shown in Fig.1. The alarm system is installed on school bus. The alarm system includes human body sensors, temperature sensor, microcontroller and speaker. Human body sensors are the FSR pressure sensors. Several FSR pressure sensors are combined one FSR array module. FSR array module and temperature sensor are connected to the input of the microcontroller, and the speakers are connected to the output of the microcontroller.

When the temperature inside the school bus exceeds 28 °C, the microcontroller starts to detect the output level of the each FSR array module. If the output voltage is low, it can be considered that one or more child is left on the school bus alone, and the microcontroller controls the relay to be powered. The normal open contact of relay will be closed and the speaker will be energized. The speaker plays an alarm sound at a high volume: "There is a child left on school bus, please check immediately." In this way, people who are closer to the school bus or who pass by the school bus can rescue the child by hearing the alarm sound.

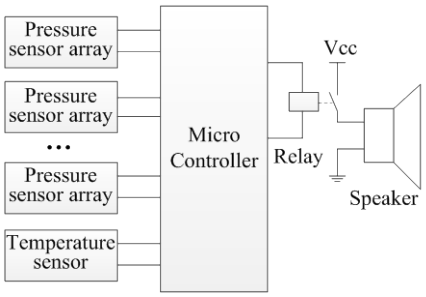


Figure 1. System block diagram

3. FSR array module design

The FSR pressure sensor is one force-sensitive sensor. When it is not pressurized, its resistance is very large, close to the 10^6 ohms. When it is pressed, its resistance decreases rapidly with the increase of pressure. When the pressure increases to a certain extent, its resistance will stabilize near a certain value, reaching several hundred ohms. Its force-resistance curve is shown in the Fig.2. Therefore, the

FSR pressure sensor can be placed on the seats, on the ground between seats, and on the aisle, and the change of the resistance can be used to determine whether a child is left on the school bus or not.

3.1. Seat array module design

There are 5 seats per row, 2 on one side and 3 on the other of school buses usually. To be able to detect child in each seat, four circular or square FSR pressure sensors are placed on each seat, and two or three seats are connected into an FSR array module, as shown in the Fig.3 in this design.

The connection diagram and equivalent circuit of the seat array module is shown in Fig.4. All FSR pressure sensors are connected in parallel, and each module has two wires leading out as an interface to other modules.

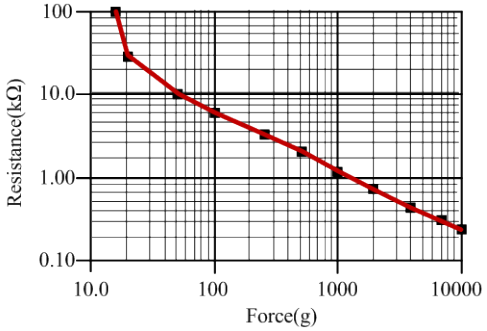


Figure 2. Force-resistance curve of FSR

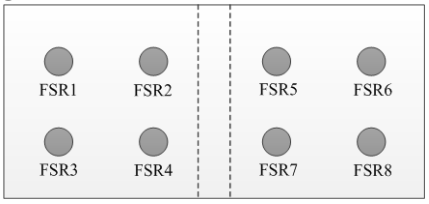


Figure 3. Sensors arrange of seat array module

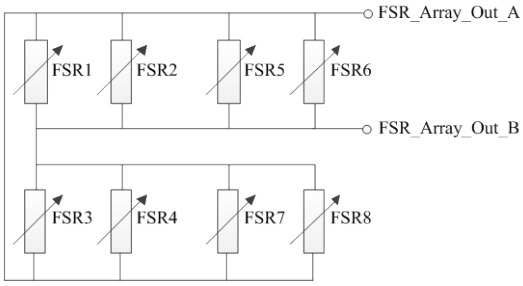


Figure 4. Connection diagram and equivalent circuit of the seat array module

$$\frac{1}{R_{Array}} = \frac{1}{R_{FSR1}} + \frac{1}{R_{FSR2}} + \cdots + \frac{1}{R_{FSR8}} \tag{1}$$

The equivalent resistance R_{Array} of each FSR array module is shown in equation (1). If all FSR pressure sensors are not pressurized, the parallel resistor R_{Array} is still large. As long as any FSR pressure sensor is pressed, the resistance is immediately reduced to several hundred ohms, and the resistance R_{Array} after the parallel connection is below several hundred ohms.

3.2. Aisle array module design

The children who are left on school bus are not sitting in the seat fixedly, or they may stand between two seats or on the aisle. Therefore, sensors need to be arranged in these places. The long strip FSR pressure sensor is selected for these places as shown in Fig.5. The length can be customized, and it is suitable for the space under the seat or the aisle. Two strip FSR pressure sensors are arranged between every two seats, and two strip FSR pressure sensors are arranged on the aisle.

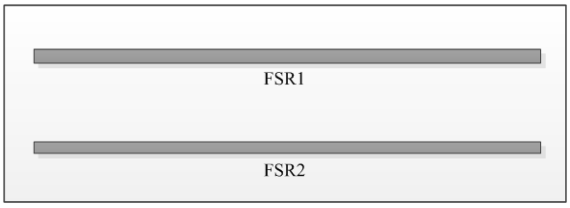


Figure 5. Sensors arrange of aisle array module

3.3. Module interface design

The interface circuit of the FSR array module is shown in the Fig.6. In the figure, the resistance of R_1, R_2 and R_3 is 10kΩ. R_x is the equivalent resistance of multiple FSR pressure sensors in parallel.

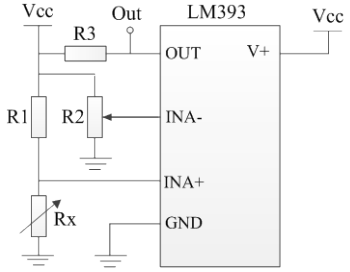


Figure 6. Module interface circuit

When the seat and aisle of the school bus are not under pressure, the resistance value of multiple FSR pressure sensors connected in parallel can still reach 10^6Ω level. At this time, the voltage of the voltage comparator (LM393) **INA+** terminal is higher than the voltage value of the **INA-** terminal (setting Value, adjustable), the **OUT** terminal output high level. If there is one or more child on the seat or aisle of the school bus, at least one FSR sensor is under pressure, and the resistance value after parallel is rapidly reduced to several hundred ohms. At this time, the voltage at the **INA+** terminal of the voltage comparator is lower than the voltage at the **INA-** terminal, and the **OUT** terminal outputs a low level. Therefore, if the **OUT** terminal is connected to one pin of the microcontroller, the microcontroller can determine whether a child is left on the school bus by the level of the **OUT** level. Several FSR array modules on several seats and on the aisle can be connected in parallel by their interfaces, and then connected to the input pin of microcontroller to save the pin of microcontroller. For example, every 5 seat FSR arrays are connected to one interface module, and all aisle FSR arrays are connected to one interface module. The 50-seat school bus requires 11 interface modules that are connected to the GPIO of the microcontroller.

4. Soft design

The working flow chart of the school bus alarm system for young children is shown in the figure 7. The temperature sensor detects the temperature inside the school bus at all times. When the temperature exceeds 28 °C, the microcontroller starts to detect the output level of each FSR array module. If the output level of any one of the FSR array modules is low, it is considered that one child is left on the school bus alone at least, and the microcontroller will drive the speaker to play an alarm sound with high volume to alert the people nearby the school bus.

Considering that children who are left on the school bus may move around, if the voltage level of the same GPIO or different GPIOs of microcontroller is detected to alternate between high and low levels, it can also be judged that one child is left on the school bus at least.

5. Module protection and system test

The FSR voltage sensor can't be directly attached to the seats of school bus when it is used. First, there is a safety hazard for young children. Second, the FSR voltage sensor is easily damaged if it is not protected. Therefore, after many tests, the FSR sensors are sandwiched in the middle of two soft silicone cushion, and the FSR array is taken out by two thin wires as shown in Fig.8.

In order to test the reliability of the children detection on the school bus, the FSR sensor was clamped in the middle of the silicone pad, and 1000 tests were performed by force from 8kg to 30kg.

When the test pressure is 8kg, there are 3 times that cannot be measured. The main reason is that the gravity is too small, and the weight of the students in the kindergarten is generally more than 10kg. Under other pressures, a few have not been detected, mainly because the pressure point is not correct intentionally.

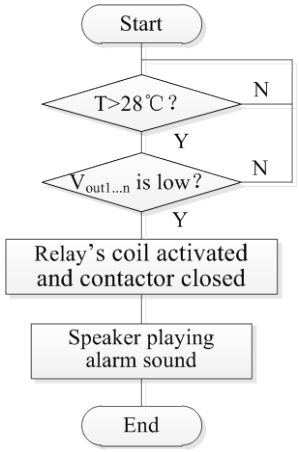


Figure 7. Flow chart of school bus alarm system

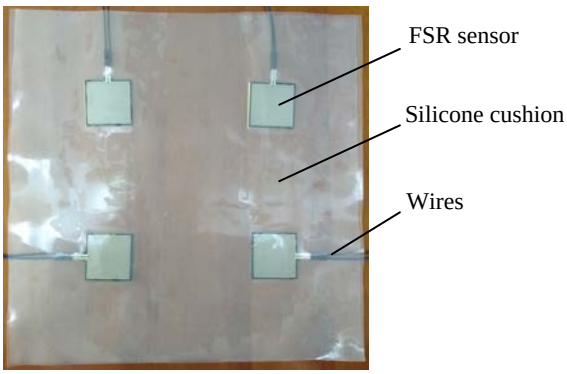


Figure 8. Protection of FSR array sensors

6. Conclusion

In view of the frequent occurrence of casualties caused by being left on school bus, one school bus alarm system based on FSR pressure sensor array was designed. The layout and protection method of the FSR pressure sensor were studied. The interface circuit of the FSR pressure sensor array was designed. The hardware and software of the alarm system were designed, and the reliability test of the system was carried out. The results showed that the alarm system could effectively detect children being left on the school bus and can alarm sound in time to facilitate rescue. The designed alarm system can be installed on the school bus to improve the safety of the children riding.

Acknowledgments

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