

Design of Elevator Condition Monitoring and Fault Alarm System

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Abstract. The elevator condition monitoring and fault alarm system comprehensively uses a variety of detection technologies, and realizes the real-time monitoring of the position, speed and acceleration of the elevator car based on the elevator condition detection. With the integration of Internet of things technology, the remote warning of elevator fault is realized, which is convenient for elevator safety inspection and maintenance. The elevator safety management platform based on the Internet of things has been established to realize the special supervision of the supervision and management department on elevator safety.

1 Introduction

As a special equipment, the elevator industry has experienced a high-speed development period[1], but in recent years, elevator safety accidents occur frequently, exposing problems in elevator design, production, installation, maintenance and supervision[2]. The development of elevator safety monitoring system cannot adapt to the growth rate of equipment, which makes the elevator safety accidents in public places and residential areas become the focus of public opinion, and brings great pressure to government departments and industry practitioners. In the process of affecting the safe operation of the elevator, the manufacturing, installation, maintenance of the elevator, as well as the owner, supervision and management departments have their own responsibilities. With the development of computer, communication and network technology, as well as the application of various detection technologies, elevator condition monitoring and fault alarm system become possible, and it has very important practical significance and urgency to ensure the safe operation of elevator and clear the responsibility of accident[3].

The elevator condition monitoring and fault alarm system is based on MEMS devices to achieve high-quality monitoring of elevator state. ADXL345 chip is selected to detect the elevator motion attitude, and obtain the vertical acceleration, angle and shaking frequency in real time. By storing the number of acceleration changes over a period of time, and dividing this number by time, we get the frequency. Based on the collected running state of the elevator, this frequency is compared with the normal shaking frequency of the elevator. If it is higher than the normal frequency, an alarm will be given. The structure of the system is as shown in Figure 1.
2 Hardware design based on adxl345

This design is composed of alarm module, ADXL345 acceleration module[4-5], remote wireless transmission module and display module. STC89C52 as MCU controls the accelerometer, and has the function of elevator position detection, fault display, remote transmission function and fault alarm. The specific system structure is shown in Figure 2.

2.1 The Basic design of ADXL345 module

The ADXL345 module has eight pins, and the functions are shown in Table 1.

| Pin Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|------------|---|---|---|---|---|---|---|---|
| Pin Name   | GND | VCC | CS | INT1 | INT2 | SDO | SDA | SCL |
| Description | Ground | Power | Chip Selection | Output of Interrupt 1 | Output of Interrupt 2 | Output of Serial Data | Input of Serial Data | Clock of Serial Port |

The measurement system of ADXL345 accelerometer has a complete function of 3-axis acceleration. It can not only measure the dynamic acceleration caused by self-stable movement or impact, such as horizontal movement acceleration, but also measure the static
acceleration. When it is fixed, it detects the vertical downward acceleration of gravity. When it acts, it detects the acceleration of X, y and Z axes. With this feature, it can detect the acceleration in three-dimensional space and the angle of inclination. Therefore, ADXL345 three-axis acceleration can be used as the tilt sensor for measuring the angle, and the distance of movement can be calculated.

ADXL345 operates as a slave in this design, so that ADXL345 adopts I2C communication, and CS is connected with +5V voltage through a pull-up resistor of 5.1k, so that it is in I2C communication mode. If CS is suspended or grounded, ADXL345 module is in sleep state. When I2C bus mode is adopted, I2C is composed of SDA (data line) and SCL (time clock line).

In this system, the single-chip microcomputer is the main device and the ADXL345 acceleration sensor is the slave device. The single-chip microcomputer initiates the start signal, generates the clock signal and the start stop signal, so as to make the ADXL345 start and stop.

### 2.2 The Mode selection of ADXL345 module

The ADXL345 sensor provides many modes, such as over run mode, FIFO mode, bypass mode, etc. in FIFO mode, if you want to sample the values in the X, Y, and Z registers, and the interrupt need to set.

In FIFO mode, the measurement data of X, Y and Z axes are stored in the address bits of FIFO. When the number of samples in the FIFO is the same as the number specified in the 0x38 address bit, the interrupt bit is set. Then FIFO continues to collect data until it fills up 32-bit registers (32 bits measured in X, Y and Z axes) and stops collecting data. Stopping collecting data here does not mean that the device stops working. In fact, the knock detection and other functions of FIFO can still be used at this time. The interrupt continues to occur until the number of FIFO samples is less than the sample bit storage value of the FIFO, CTL register. It can ensure the full delay of FIFO reading.

Read FIFO data in addresses 0x32 to 0x37. When the accelerometer is in FIFO mode, the X, Y and Z registers read the data stored in FIFO. The data is read from the FIFO, and the oldest data on the X, Y and Z axes is stored in the X, Y and Z registers. If only a single byte read operation is performed, there is a risk that the bytes of the current FIFO data sample will be lost. Therefore, all target axes are read by multibyte read operation, which can reduce the risk of byte loss. In order to ensure that FIFO is ejected completely, after reading the data register and before reading the FIFO re reading or FIFO status register, delay at least 5μs, and change the register 0x37 to register 0x38 or the pin to high level as the sign of reading the end of the data register.

### 2.3 The parameter setting of ADXL345 module

#### 2.3.1 The accuracy of X, y and Z axes

The addresses 0x32 to 0x37 are 8-byte registers used to store the output data of each axis. The addresses 0x32 and 0x33 are used to save the data output by X-axis, 0x34 and 0x35 are used to save the data output by Y-axis, 0x36 and 0x37 are used to save the data output by Z-axis, the output data is binary complement, datax0 is low significant byte, datax1 is high significant byte, where x represents X, Y, or Z-axis. The address 0x31 controls the format of the data.
2.3.2 The measurement range

The measurement system of ADXL345 accelerometer has a complete function of 3-axis acceleration. It can choose the acceleration measurement range of $\pm 2g$, $\pm 4g$, $\pm 8g$, $\pm 16g$, and can be set by the register of $D0$ and $D1$.

2.3.3 The resolution settings

When the $FULL\_RES$ is high, the device is selected as the full resolution mode, and the scale of the output resolution increases the scale factor of 4mg/LSB. When set to 0, the device is in 10 bit mode, and the selection of $g$ will determine the scale factor. For example, when $2g$ is selected, the resolution is $2/2^{10}\text{mg/LSB}=3.9\text{mg/LSB}$.

3 Warning strategy design

The alarm module is the important part of the whole program design. Through many tests, if it is found that the normal acceleration of the elevator is between $0.05\text{m/s}^2$ ~ $0.2\text{m/s}^2$, the elevator will fail. All we have to do is to give an alarm when the elevator is in such a situation, remind the maintenance personnel to come for maintenance, and remind the people who come to take the elevator of the elevator failure. In this project, the alarm strategy is mainly determined by the following situations:

1. When we detect that the acceleration of $Z$-axis exceeds the threshold value of normal elevator acceleration, it means that the elevator is in abnormal vibration, and the buzzer gives an alarm.

![Figure 3. System program flow chart.](image)
2. When the Z-axis displacement exceeds the set threshold value of normal operation of the elevator, it is proved that the elevator may fail. At this time, the buzzer will sound and give an alarm.

3. When the acceleration of X, Y and Z axis exceeds the set threshold value at the same time, the buzzer will give an audible alarm.

4. In the buffer area of the alarm program, the number of acceleration changes in a period of time is stored, and the frequency is compared with the frequency threshold of normal shaking of the elevator. If the frequency is greater than the normal frequency, the alarm program will also be triggered.

The system program flow chart is shown in Figure 3.

4 Conclusion

The design of the elevator condition monitoring and alarm system based on MEMS adopts ADXL345 acceleration sensor to obtain the acceleration of X, Y and Z axis, so as to calculate the angle and vibration frequency of each axis according to a series of algorithms. Then compared with the threshold value of normal operation of the elevator, if it is beyond the normal range, it will be judged as elevator fault, and the buzzer will be triggered, so as to alarm through the wireless transmission function.

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