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Tire Pressure Monitoring and Alarm System Based on GSM SMS

Zihan Lin
Yangtze University
School of Electronic Information and Electrical Engineering
Jingzhou City
Hubei Province, China

Yong Wei
Yangtze University
School of Electronic Information and Electrical Engineering
Jingzhou City
Hubei Province, China

Abstract: To address the driving safety issues caused by abnormal tire pressure in vehicles, this paper designs a tire pressure monitoring and alarm system based on GSM SMS. The system uses an STC89C52 single-chip microcontroller as the controller, and designs the tire pressure acquisition circuit, LCD display circuit, buzzer circuit, LED light circuit, and GSM SMS sending module circuit. The monitoring effect of the system is simulated and verified by circuit simulation software, and the circuit system is fabricated and tested. Results show that the designed tire pressure monitoring and alarm system can realize tire pressure monitoring. When the tire pressure is within the standard range of 220 kPa to 240 kPa, the relative error of the actual measurement results does not exceed the threshold of 4%. Moreover, when the tire pressure is abnormal, it can promptly achieve on-site alarm through the buzzer and LED lights, and remote alarm through the GSM module, thus achieving the expected effect and having strong application value.

Keywords: Tire Pressure Monitoring and Alarm System; STC89C52; GSM SMS sending module; On-site Alarm; Remote Alarm

1. Introduction

With the development of technology and the improvement of people's living standards, automobiles have entered ordinary households and become the current mainstream mode of transportation. Meanwhile, their safety issues have attracted widespread attention. Among them, the driving safety problems caused by abnormal tire pressure of automobiles have become increasingly serious. Therefore, the tire pressure monitoring and alarm system plays a very important role in the driving safety of automobiles. Deng Rukui et al. aimed at the problem of how to transmit data, used the CAN bus to send data to the platform side, and displayed the real-time information of truck tire sensors on the platform. Jiang Jiwen et al. adopted Zigbee technology to transmit data to the main control module, which was processed by the MCU controller and displayed by the liquid crystal display. Although such methods realize data transmission within a certain range and facilitate users to monitor tire pressure, they have shortcomings in long-distance transmission. When users are in areas non-adjacent to the automobile, if abnormal changes occur in tire pressure, users will be unable to obtain real-time information about the abnormal situation, which may further lead to inconvenience for users when using the vehicle.

Based on the above status quo, this paper designs a tire pressure monitoring and alarm system with the STC89C52 single-chip microcomputer as the controller. The system can monitor tire pressure in real time. In the case of abnormal tire pressure, it carries out on-site alarm through LED lights and buzzers, and at the same time, uses the global mobile communication system to send text messages containing tire status information to users' smart phones, so as to realize the remote alarm function, thereby ensuring that users can timely and accurately understand the real-time status of tires. Through simulation and experimental verification, the system has good stability and reliability.

2. Measurement Principles and Methods

According to their working principles, tire pressure monitoring systems can be divided into direct type and indirect type. Direct tire pressure monitoring uses pressure sensors to directly measure the tire pressure. The indirect tire pressure monitoring system compares and analyzes the rotational speed differences between tires through signals from wheel speed sensors and lateral acceleration sensors. When the tire pressure decreases, the vehicle's mass causes the tire diameter to become smaller, triggering an underpressure alarm through this change. This system adopts the direct tire pressure monitoring method, installing an integrated pressure sensor on the valve inside the tire to directly sense and measure the tire pressure. The measurement principle is shown in Figure 1.

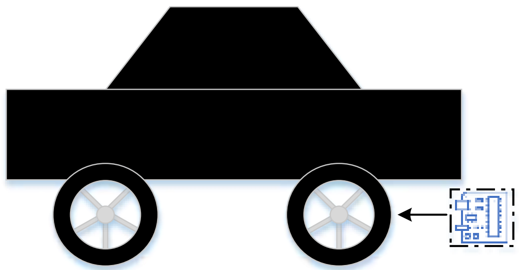

Figure. 1 System Measurement Schematic Diagram

3. System Overall Design

The overall system framework is shown in Figure. 2. Taking STC89C52 as the core control unit, the system integrates a tire pressure acquisition module, which can real-time acquire the air pressure data inside the vehicle tires and instantly display this information through an LCD screen. On this basis, the system continuously compares and analyzes the actual measured tire pressure values with the preset normal tire pressure range. Once the tire pressure is found to deviate from the normal range, the system will immediately trigger the alarm mechanism, specifically manifested as the buzzer sounding and the LED indicator lighting up. Meanwhile, the system also sends SMS notifications to the user's mobile phone through the GSM SMS sending module, reminding the user of the current tire pressure abnormality.

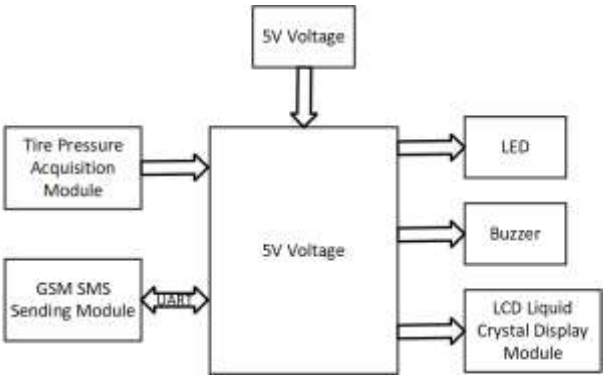

Figure. 2 Overall System Framework Diagram

4. System Hardware Circuit Design

4.1 Tire Pressure Acquisition Circuit

The tire pressure acquisition circuit is shown in Fig. 3. Air pressure data is converted by the pressure sensor and mapped to the corresponding analog voltage signal. Since the single-chip microcomputer cannot directly process analog signals, an AD converter is required to convert the captured analog voltage signal into a digital signal format. The single-chip microcomputer then reads the digital signal values output by the A/D converter through its P2.3 and P2.4 pins according to the serial peripheral interface (SPI) bus protocol, and further performs corresponding data processing and analysis operations.

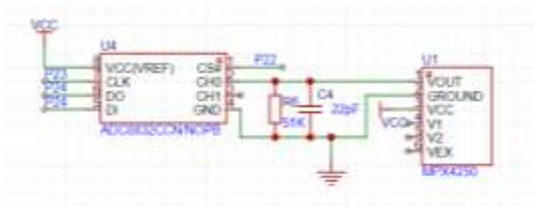

Figure. 3 Tire Pressure Acquisition Circuit

compare the externally input analog voltage signal with a preset reference voltage and then convert it into a digital signal that can be parsed by the microcontroller. During the quantization and encoding process, the ADC0832 divides the reference voltage into 256 levels (i.e., 2^8), each corresponding to a digital quantity ranging from (00000000)B to (11111111)B. The converter uses the successive approximation method to accurately convert the input analog voltage into the corresponding digital quantity. The microcontroller can read the conversion result through serial communication. Since the data output by the ADC0832 is in binary form, while the system processing requires decimal values, a conversion formula is needed:

$$Vary = \sum_{i=0}^{7} D_i \times 2^i \quad (1)$$

The conversion is performed using the above formula, where D0 to D7 represent the least significant bit (LSB) to the most significant bit (MSB) of the read binary number, respectively.

The pressure sensor selected is the MPX4250 absolute pressure sensor produced by Motorola. It generates a micro-scale voltage signal through silicon piezoresistive elements, with a proportional relationship between the voltage signal and the measured pressure [11-12]. As shown in Fig. 4, the three lines from top to bottom represent: the maximum error value, the ideal value, and the minimum error value.

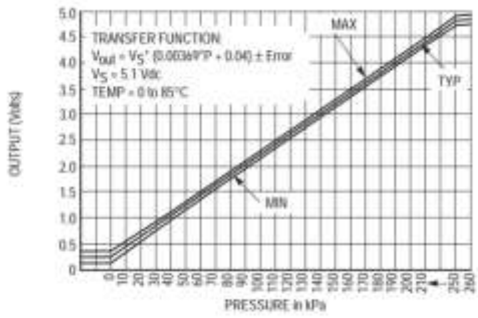

Figure. 4 MPX4250 Linear Relationship Diagram

As shown in the figure, the supply voltage V_S of the MPX4250 is 5.1V. Within the ambient temperature range (0°C to 85°C) of normal vehicle operation, the A/D converter divides the reference voltage (5V) into 256 levels. Based on the linear relationship between air pressure and output voltage, we can derive the linear interval scaling transformation formula for pressure:

$$press = \frac{\frac{Vary \times 5.1}{256 \times 5} - 0.04}{0.00369} \quad (2)$$

Convert the voltage value into a pressure value, where the unit of the pressure value (press) is kPa.

4.2 LCD Liquid Crystal Display Circuit

The LCM1602 liquid crystal display module is selected as the component for real-time data presentation. Its low power consumption during operation ensures reliable long-term stability, thereby enabling an efficient and high-quality human-machine interaction experience. The pin functions are shown in Table 1.

Table 1. LCM1602 Pin Function Table

Number	Symbol	Pin Description
1	VSS	GND
2	VDD	5V Positive Power Supply
3	V0	Contrast Control Terminal
4	RS	Register Selection
5	RW	Read/Write Selection Terminal
6	E	Enable Signal
7-14	DB0~DB7	Data Bus

The LCD liquid crystal display circuit is shown in Figure. 5. The P0 port of the STC89C52 microcontroller is used for data and instruction transmission. The enable signal (EN), register select signal (RS), and read/write signal (RW) of the LCD are connected to the P2 port of the microcontroller to effectively control the working enable state and read/write operations of the LCD. In addition, the LCD is powered by a 5V DC power supply, and a 2kΩ resistor is connected in series to optimize its contrast, ensuring that the display content achieves the best clarity.

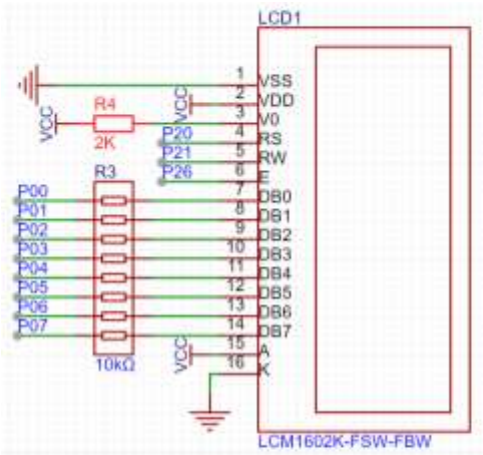

Figure. 5 MPX4250 Linear Relationship Diagram

4.3 The buzzer circuit and LED light circuit

The buzzer circuit and LED circuit are shown in Figure. 6 and Figure. 7, respectively. The I/O ports of the STC89C52 microcontroller output TTL level signals, but the driving current of this level is insufficient to directly drive the buzzer. Therefore, an NPN transistor is used as a current amplifier to increase the current to a level capable of driving the buzzer. Meanwhile, the switching characteristics of the transistor are utilized to achieve effective control of the buzzer. When the I/O port outputs a high-level signal, the transistor is in the conducting state, causing the buzzer to start working; conversely, when the I/O port outputs a low-level signal, the transistor is cut off, and the buzzer stops working immediately.

For the LED (light-emitting diode), it has the physical characteristic of unidirectional conductivity. When the I/O port outputs a low-level signal, the LED diode is in the conducting state and lights up; when the I/O port outputs a high-level signal, the LED diode is in the cut-off state and thus turns off.

When abnormal tire pressure is detected, the buzzer and LED indicator work in coordination to achieve real-time on-site alarm function. This design aims to ensure that users around the vehicle can quickly and accurately identify the occurrence of abnormal tire pressure.

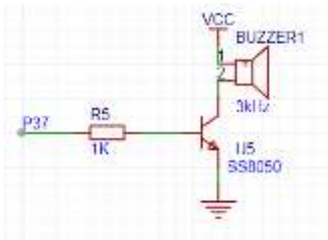

Figure. 6 Buzzer Circuit

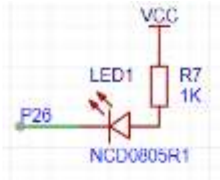

Figure. 7 LED Circuit

4.4 GSM Short Message Service Sending Module Circuit

If the user is at a long distance from the vehicle, the on-site alarm system cannot promptly notify the user, causing the user to discover abnormal tire pressure only when using the vehicle, which in turn makes normal driving impossible. This undoubtedly brings great inconvenience to the user. In view of this problem, while retaining the on-site alarm function, this design innovatively introduces a GSM short message service (SMS) sending module, aiming to achieve the remote alarm function for abnormal tire pressure.

The module uses a SIM800C GMS SMS sending module, which can realize SMS sending and receiving with low power consumption. During the communication process, the SIM card sends corresponding Attention (AT) commands to it through the serial port module (UART) of the STC89C52 microcontroller to realize SMS sending and receiving. The instructions for SMS receiving and sending functions are shown in Table 2.

Table 2. SIM800C SMS Sending and Receiving Command Table

Command	Pin Description
“AT+CMGF=1\r”	Configure the SMS format
“AT+CMGL=\”ALL\ ”\r”	Read all SMS messages
“AT+CSCS=\”GSM\ ”\r”	Perform CSCS settings
“AT+CMGS=”	Add a short message number
“AT+CMGD=”	Delete SMS messages

When the monitoring system identifies that the tire pressure value of the vehicle is in an abnormal state, the microcontroller can control the SIM800C through the serial communication port to send an alarm text message to the user's mobile phone. This allows users to promptly obtain tire status information even when they are not around the vehicle, enabling real-time monitoring of vehicle tire conditions and timely response.

5. System Software Design

5.1 Overall Software Program Design

The overall software program design is shown in Figure. 8. After the system is powered on and started, it first performs initialization configuration of relevant modules. The system then uses a pressure sensor to measure the tire pressure value, and the acquired data is displayed in real time through an LCD. Immediately after that the system compares and analyzes the measured tire pressure value with the preset normal tire pressure range. If the tire pressure is in a normal state, the system will continue the next round of tire pressure measurement. If an abnormal tire pressure value is detected and this abnormality is detected for the first time, the system will immediately send a text message alarm to the user's mobile phone through the GSM SMS sending module to remind the user. Meanwhile, the system will activate the buzzer to emit a sound alarm for 30 consecutive seconds and turn on the LED indicator as a visual alarm signal. After completing these alarm operations, the system will measure the tire pressure value again. If the system detects tire pressure abnormality for non - first time, it will only turn on the LED indicator as an alarm signal and then re - measure the tire pressure.

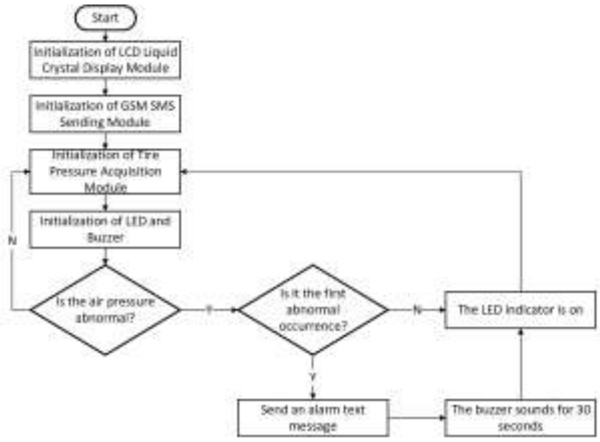

Figure. 8 Overall Software Program Design Diagram

5.2 Software Design for Tire Pressure Acquisition

The data acquisition process is shown in Figure. 9. The tire pressure acquisition can be broken down into two core stages: data collection from the pressure sensor and data conversion calculations. Before each data acquisition, the single-chip microcomputer (MCU) needs to send a start signal to the ADC chip to activate it into the working state. Subsequently, the system selects a channel to collect data and stores the acquired data in a preset array. To enhance data accuracy and reliability, the system performs ten repeated reading operations. After completing all readings, arithmetic averaging is performed on the ten sets of data, and the resulting average value is taken as the final valid data value.

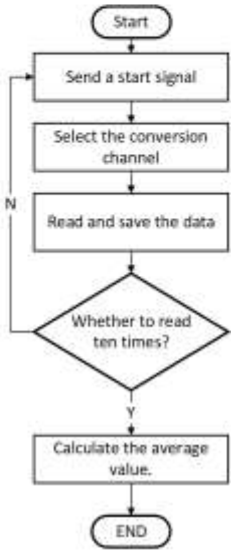

Figure. 9 Data Acquisition Flowchart

5.3 Software Design for GSM SMS Sending

The GSM SMS sending process is shown in Figure. 10.Before using the SIM800C module for SMS sending operations, the primary step is to configure it into the SMS communication mode. Subsequently, the target number for receiving the SMS needs to be clearly set. After completing the number setting, the SMS content to be sent is transmitted to the module, and this process continues until the SMS is successfully sent.

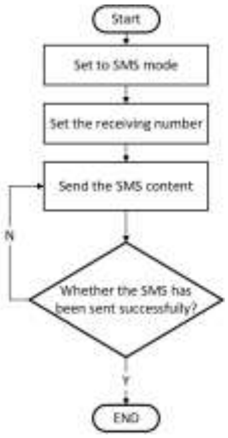

Figure. 10 GSM SMS Sending Flowchart

6. System Overall Testing

The system is simulated and tested by adjusting the pressure sensor in Proteus to simulate the actual tire pressure values. The schematic diagram of the simulation test is shown in Figure 11.

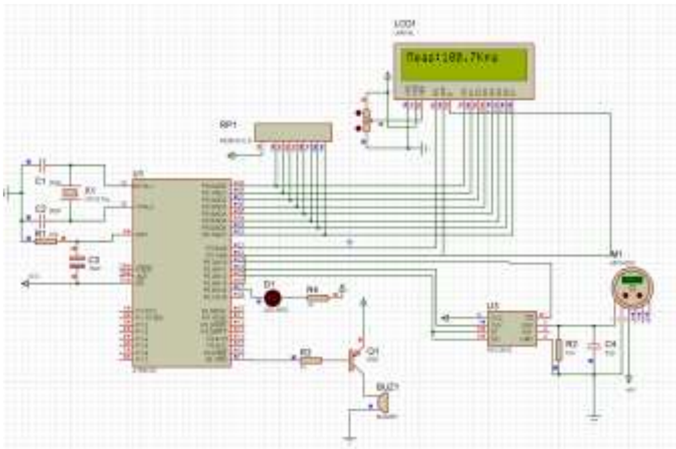

Figure. 11 System Simulation Schematic Diagram

Set the tire pressure threshold at 220-240 kPa, change the input value of the pressure sensor, and the measured data are shown in Table 3.

Table 3. System Simulation Test Results

Number	Pressure input value / kPa	Pressure output value / kPa	Buzzer/ LED
1	200	199.1	On
2	205	204.1	On
3	210	209.3	On
4	215	214.7	On

5	220	219.4	On
6	225	224.6	Off
7	230	229.7	Off
8	235	234.9	Off
9	240	240.2	On
10	245	245.4	On

After the simulation test, a physical prototype was manufactured to conduct operational testing on the system. The physical diagram is shown in Figure 12.

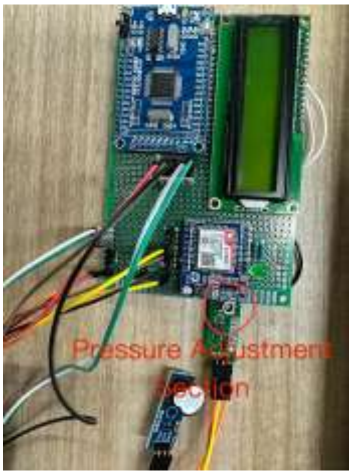

Figure. 12 System Physical Diagram

Set the tire pressure threshold at 220-240 kPa, use a syringe and a hose to inject gas into the tire pressure sensing element, thereby regulating and simulating the actual tire pressure values. Test the system's operation under these conditions, and the data obtained are shown in Table 4.

Table 4. System Test Results

Number	Pressure input value / kPa	Pressure output value / kPa	Buzzer /LED	SMS
1	200	198.3	On	On
2	205	203.4	On	On
3	210	208.7	On	On
4	215	214.1	On	On
5	220	219.4	On	On
6	225	224.8	Off	Off
7	230	230.1	Off	Off
8	235	235.5	Off	Off
9	240	240.8	On	On
10	245	246.2	On	On

By subtracting the pressure output value from the pressure input value, the magnitude of the error can be obtained. The simulation error magnitude and the measured error magnitude are shown in Figure 13.

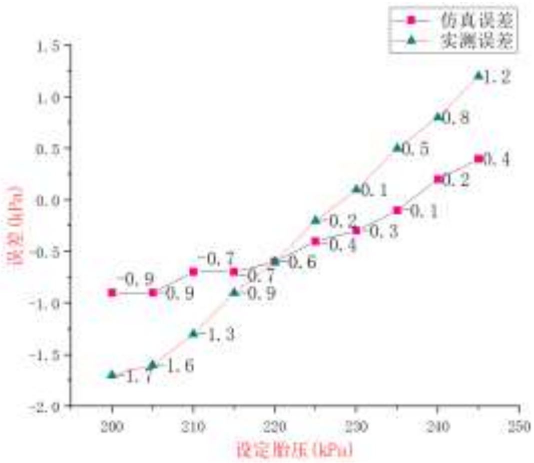

Figure. 13 Simulation and Measured Pressure Error Diagram

It can be seen from the above figure that within the pressure range of 200-250 kPa, the simulation error does not exceed 1 kPa. Meanwhile, the measured error range also does not exceed 2 kPa. Within the normal tire pressure range (220-240 kPa), the measured relative error does not exceed 4%, verifying the system's high measurement accuracy. Additionally, all alarm modules of the system can operate normally under set conditions, with no false alarms or missed alarms, reflecting the system's good reliability. In conclusion, the system demonstrates excellent performance in measurement accuracy and timely alarming, showing high practical value.

7. Conclusion

To achieve real-time detection of tire pressure anomalies and promptly notify users upon detecting abnormal conditions, this paper presents a design for a tire pressure monitoring alarm system based on GSM short messages. Building on the technical solutions of traditional tire pressure monitoring alarm systems, the design introduces a pressure sensor as the core sensitive component for monitoring and integrates a GSM SMS sending module. The system can not only issue on-site alarm signals but also enable remote SMS alarm functions. This design significantly enhances the human-computer interaction performance of the system, allowing users to monitor tire pressure conditions anytime and anywhere, demonstrating strong practical value and broad market application prospects.

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