Study of Car Tyre Monitoring System Based on CAN Bus

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Abstract—**Tyre fault detecting is important to car safety when it running. Therefore, CAN bus-based car tyre monitoring system is designed to monitor the status of tyre in real time. Firstly, the whole car tyre monitoring system is designed in general. Secondly, the design for system hardware is carried out. Thirdly, the software of system is designed. Finally, the simulation verification results show that the system is able to monitor the status of car tyre in real time effectively and safe running of the car can be ensured.**

Keywords—Car tyre; CAN bus; Monitoring system; Hardware design; Wireless sensor

I. INTRODUCTION

Car tyre fault is usually occurred when car running at high speed. And it is the main inducement for car accidents. As tyre pressure leakage is very dangerous, therefore, to prevent car accidents from tyre leaking, it is of great significance to design a tyre status monitoring system based on CAN bus. At present, the research on tyre status monitoring system is thriving. Car drivers can rely on the existing tyre monitoring system to well understand how the tyre pressure and temperature change in real time. The monitoring results of present systems are good, but their disadvantages still exist. The present monitoring system is only applicable to small vehicle. However, the system reliability is reduced significantly due to expanding electronic control unit, improved complexity of cabling, longer transmission distance, serious interference as well as shield signal when applied to big vehicles [1].

In order to avoid the disadvantages of traditional tyre monitoring systems, new tyre status monitoring system solution is designed. Tyre monitoring system is installed on every tyre of the car, each monitoring system act as a node point to build a CAN bus, accordingly, parameters like tyre pressure, temperature can be monitored dynamically and the real time tyre parameters are transmitted to the cab for processing with CAN bus at the same time. In this way, timely alarm is activated once tyre fault is detected and the traffic accident can be prevented accordingly.

II. GENERAL DESIGN OF THE CAR TYRE MONITORING SYSTEM

CAN bus-based car tyre monitoring system consist of two parts, hardware and software. The hardware mainly consists of master computer, USBCAN, microcontroller, CAN controller, CAN bus transceiver and sensors that are used for monitoring the car tyre status. Handheld PAD or laptop can be used as the master computer; USBCAN is used to connect the master computer and the slave computer, and intellectual interface card is usually used as the interface; a common 51 single-chip microcomputer can be used as the microcontroller to receive instructions from the master computer, respond to master's requests and control the sensors of the system. The CAN controller is used to connect the single-chip microcomputer and the CAN bus, it is able to control the system sensors via the CAN bus. CAN transceiver ensures multi equipment can access the CAN bus resources. Temperature sensors and pressure sensors are mounted on the tyres as measurement devices, thus data can be tested and transmitted. The temperature and pressure range, as well as the cabling difficulties of the tyre are need to be put in consideration, the power supply and power consumption are required to be considered at the same time as well. The communication protocol of the tyre status monitoring system is based on CAN2.0A. A standard CAN2.0A include 11-bit ID, 1-bit RTR, 4-bit DLC and a data field which is not exceed 8 bytes [2].

The system software design mainly includes configuring system communication, system parameter and system management. By programming with MATLAB 7.0, application that meets the needs of tyre status monitoring system can be developed. The system software design mainly includes three parts, which are software interface design, data base design and key modules design. Interface design includes menu bar, tool bar, side bar, monitoring area bar and status bar; Data base design is aim at store data information with SQL Server 2000. Key modules design includes designing of communication and monitoring modules. In the communication module, acquisition terminal initialization, search and shut-down operations are achieved with the DLL of USBCAN. The monitoring module is designed to display the real time status information of the tyre. Car tyre status monitoring module is

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designed to process and display the data in the simulation environment and CAN bus analyzer is used to debug the module. And a testing module with warning capability is designed as well. Therefore, it is able to test the overall system performance [3].

III. HARDWARE DESIGN OF CAR TYRE MONITORING SYSTEM

A. The tyre module s

The tyre module use active and direct tyre pressure monitoring method to monitor the temperature and pressure parameters that can influence the tyre performance. This module is mounted inside the wheel, tyre valve or tyre, and lithium battery is used as the power supply. This module communicates with the CAN bus via wireless communication technology. This module mainly consists of temperature sensor, pressure sensor, wireless RF emitter and MCU. In order to meet the requirements of monitoring in a situation with high temperature, excessive vibration and humid ambient, the pressure and temperature senor need to be accurate in measuring, low demand in energy consumption and long lasting in service life. SP12 sensor is selected when designing the tyre module, as the SP12 sensor integrates pressure, temperature and acceleration, as well as battery voltage detections all together. In normal situation, SP12 does not carry built-in MCU, therefore, an external processor is required, to receive 125kHz wake-up signal and at the same time to make sure the RF emitter works properly at different modes [4].

In terms of selecting the wireless RF emitter, the reliability of signal transmission need to be considered when the car running at high speed. General speaking, signal is not continuous when the car running at high speed and in rough situations like high temperature, excessive vibration and humid ambient. Besides, mobile phone and audio speaker impact signal reliability as well. Therefore, single-chip RF emitter with TDK510XF chip is selected for the design. The frequency band of this RF emitter is 433-435MHz and there is a PLL synthesizer built inside. It's an efficient amplifier and presents in a loop-antenna manner. The working temperature of this RF emitter range from -40℃ to 125℃. The circuit arrangement is special, the amplifier is low in energy consumption and the battery is long lasting in service. It is small encapsulated and highly integrated. Therefore, this RF emitter is very suitable for car tyre monitoring application.

B. Node point design of wireless sensor

Hardware design of wireless sensor network node mainly includes three modules: sensor module, MPU module and wireless communication module. Please see the Figure 1 for the hardware structure [5].

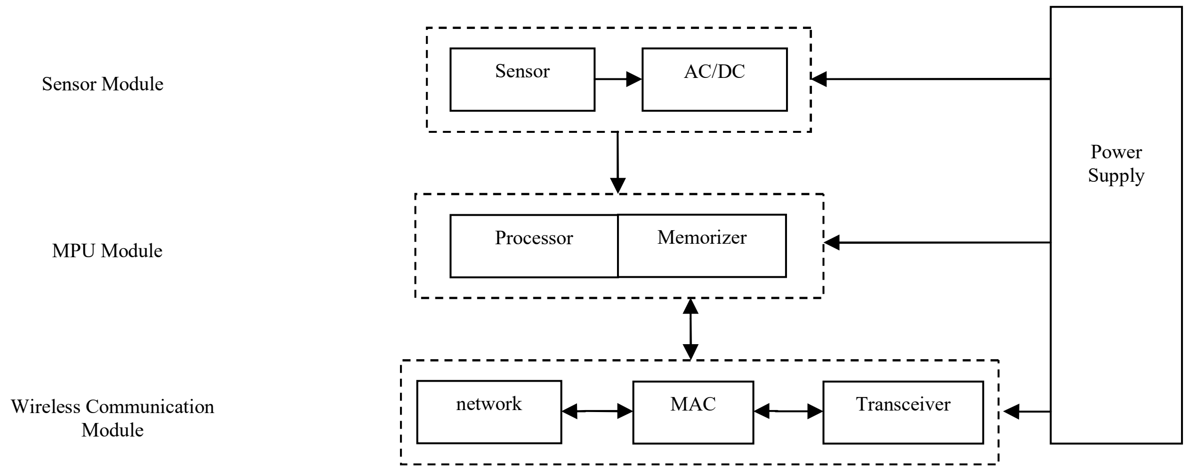

Figure 1.Structure of wireless sensor network node

GAINTS series nodes are designed as the processing core and controller with the single chip computer. 433MHz single-chip low voltage transceiver is used for the wireless sensor network and the transceiver model is CC1000. This RF chip has a lot of advantages, like low demand in energy consumption, low working voltage, small size and highly integrated. It is able to connect with the microprocessor by using FSK debugging mode and SPI interface externally. Crystal oscillator with the frequency at 14MHz is used as the CC1000 driver. The data transfer rate is 19.2KB/s and related parameters are set according to the ACK and RTS-CTS waiting time.

C. Design of communication protocol

TinyOS low-level communication interface is applied as the communication protocol. It is programmed with nesC programming language, which is the expansion of the C programming language, and it is also a structured language. Programming applies modularization mode. Components of nesC include module and connection profile. Main function of the former is to write code, therefore to provide an interface. TinyOs is a module structured, open source embedded operation system. An application can use the wiring specification to connect different modules together, thus realize the required functions. Applications of TinyOS are mainly event-driven, they are triggered by events and thus activate the sensors. Tasks are usually used in the circumstances with lower requirement on the time. And relationships among tasks are even, which is to say they are running successively. In normal situation, to reduce running time of tasks, tasks need to be short and small, in this case the burdens of the system is reduced; Events are usually used in the circumstances with higher requirement on the time. They are able to run with other events prior to the tasks, and are also able to be triggered by an operation or external event. Normally, TinyOS realizes event driven by hardware interrupt processing. As tasks run in a non-preemptive way among each other in TinyOS. Therefore it is impossible for TinyOS to provide any blocking operations. To complete a time-consuming operation with less time, the usual method is to complete this operation separately based on the demands and thus high implementation efficiency is obtained. This is all because process management does not exist in TinyOS, tasks are proceed in a simply FIFO queue and resources are assigned in advance, besides, there are at most seven unsolved tasked are allowed in this queue. Three kinds of events need to be addressed during the design process: receiving data wirelessly, serial port data receiving and timer events.

D. Car tyre receiver

Monitoring receiver includes RF receiving circuit, single-chip computer, CAN controller, communication module and power supply, see Figure 2.

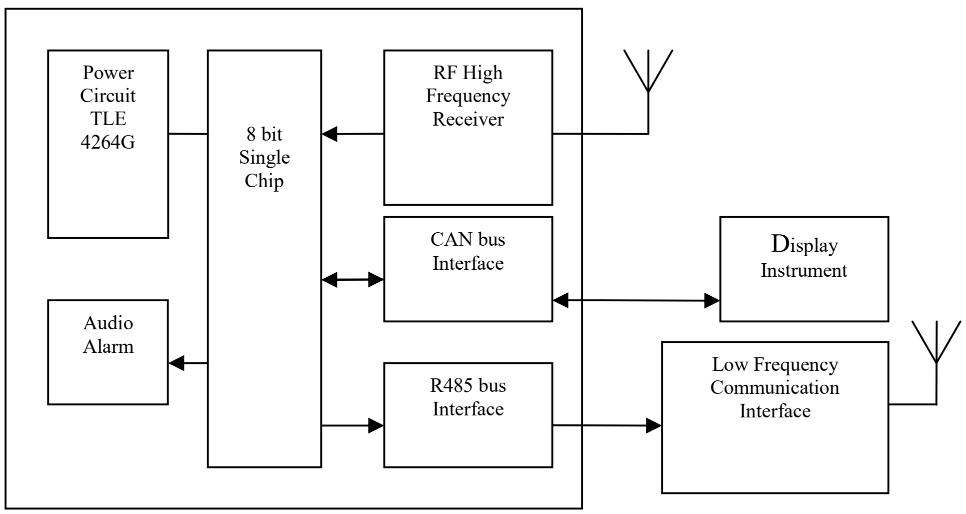

Figure 2. Monitoring Receiver Diagram

RF high frequency receiving circuit is able to receive the wireless signal that is transmitted by the sensor module, then signal smoothing, amplifying and demodulating are implemented. Finally, the signal is send to the single-chip for processing. The single-chip compares the control interval with the pressure and temperature received. Alarm output signal is sent when the detected value is not in the control interval, therefore, audio alarming begins. In the receiver, the single-chip use CAN controller to send the detected results to the display instrument and the results are hence displayed [6].

Monitoring receiver use RS485 bus to control low frequency communication module and transmit 125 kHz signal to the wireless sensor module, thus two-way signal transmission is achieved. Monitoring receiver can reset the related parameters of wireless sensor module. It is able to make the sensor module collect and transmit data and can also collect and transmit the frequencies of related parameters based on the tyre control sensor module. The monitoring receiver triggers different wireless sensor modules separately and receive ID number-included information from them to complete car tyre monitoring. Once sensor module fault occurs, the monitoring receiver can address it in time. This is because in a same period of time, only one sensor module communicates with the monitoring receiver. Accordingly, the communication conflict is avoided.

IV. SOFTWARE DESIGN OF CAR TYRE MONITORING SYSTEM

Wireless communication carrier frequency of the car tyre monitoring system is designed to 412.34 MHz and transmission speed is designed to 9420 bps. The FSK debugging mode is applied and Manchester coding is needed for the data frames before transmitting. In Manchester coding, digital signal 0 or 1 are expressed by the level transition between two bit periods. A 0 is expressed by a high-to-low transition, while a 1 is expressed by a low-to-high transition. Manchester code can reduce the dc component of the transmitting signal and bit error rate, at the same time increase the communication distance and improve the anti-interference ability of data.

Wireless communication of the car tyre monitoring system is achieved by the length of data frames. The related data frames include lead code (16-bit), synchronization header (16-bit), tyre ID No. (32-bit), temperature (8-bit), pressure (8-bit), voltage (8-bit), status word (8-bit), checksum (8-bit) and stop bit (2-bit). 16-bit lead code transmits the 1 of Manchester code, thus the receiver can establish synchronous clock and get ready to receive operation at the same time. The synchronization header is 16-bit OxFB86, OxF(1111) 4-bit preamble can awake the receiver and maintain the reliability of the internal circuits. OxB8 is the smoothing register value of the receiver, when the smoothing register value equals the value of smoothing register in the receiver, the receiver starts to receive signal. Tyre ID is 32-bit, this frame of data is transmitted. By comparing the tyre ID number with software, it is able to know which tyre sends out the data. It is certain that the data is transmitted by other tyres when the ID is different with the pre-stored one, and therefore this frame of data can be ignored. Bytes number of pressure, temperature and voltage are 8 bytes, which indicate the parameters obtained by the tyre module testing. In order to improve the anti-interference level of the data, Manchester codling is applied and decoding it at the receiving end according to the format of the data frame. Status words are used to indicate different faults of the tyre module, for example, line broken of the sensor, low voltage of the battery etc. In order to reduce the rate of false alarm and quickly identify false code, 8-bit checksum is designed at the end of the message. The summation of this checksum data and the tyre ID number, pressure, temperature, voltage and status equals 0. Therefore, the receiver can identify that if false alarm happens during the transmitting period simply by using software. The bytes number of the stop bit is 2 bytes, which is used to indicate the termination of data frame.

V. SOFTWARE DESIGN OF CAR TYRE MONITORING SYSTEM

Software workflow of car tyre monitoring system is showing in Figure.3.

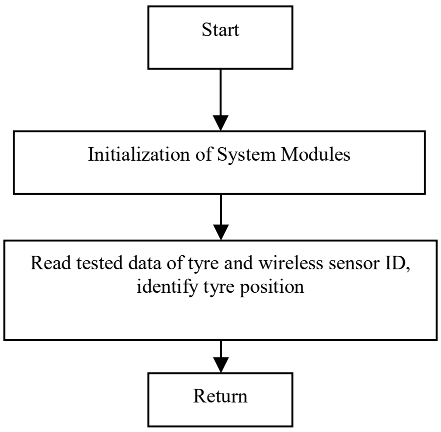

Figure.3 Design workflow of Car Tyre Monitoring System

In order to verify the validity of the designed car tyre monitoring system, simulation test is implemented. The simulation testing system is developed with MATLAB 7.0. When monitoring a car, time interval of wireless sensor data transmitting is set as 6 minutes and one data frame is transmitted each time. Monitoring results of tyre internal pressure and temperature are showing in Figure. 4 and Figure. 5.

Based on Figure.4 and Figure, the tyre internal pressure and temperature change over time. Therefore, working status of car tyre can be obtained. Alarm is activated in time once tyre fault happens, thus serious car accidents can be avoided.

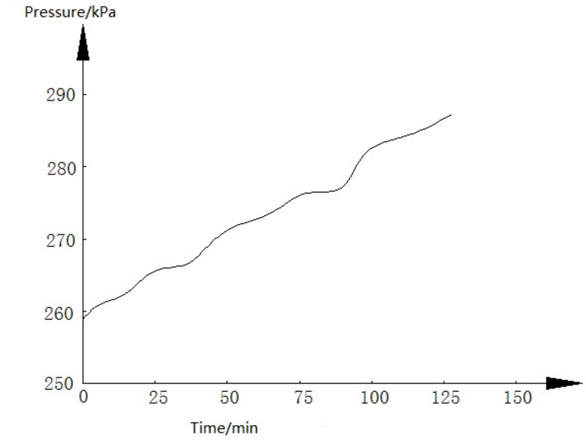

Figure.4 Monitoring Results of Tyre Pressure

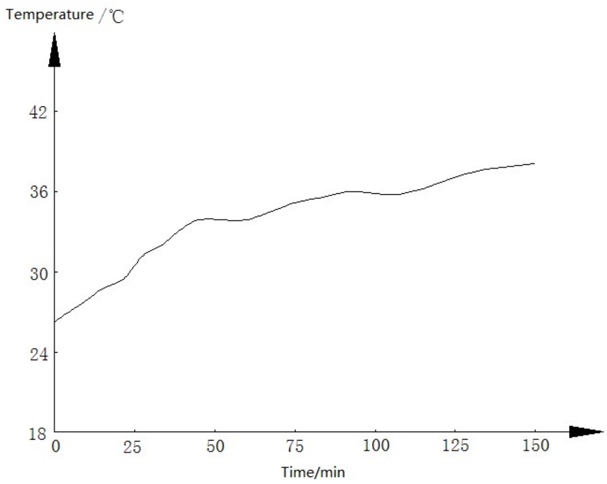

Figure. 5 Monitoring Results of Tyre Temperature

VI. CONCLUSION

CAN bus-based tyre monitoring system apply new solution. Tyre status monitoring system is mounted for each tyre, therefore, real time tyre status can be transmitted to the central control node, data processing and displaying are achieved and system alarming ability is improved as well. By integrating CAN bus and sensor technology into tyre status monitoring system, dynamic situation of tyre status parameters (ambient temperature, ambient humidity, elevation etc.) can be obtained, thus improve the performance of tyre monitoring system. By introducing CAN bus to the tyre status monitoring system, it is able to coordinate the tyre status monitoring system and other electronic control system. It can also improve the overall system performance, reduce the cost and make the car more comfortable and safe. CAN bus-based tyre status monitoring system can remedy the disadvantages of traditional monitoring system. It not only improves transmission distance and the number of terminal nodes, but also improves the real time performance of the data communication. Accordingly, the tyre monitoring system becomes more flexible and reliable.

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