ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology
Volume 1, Issue 4, June 2012

Wireless Tire Pressure Monitoring System for Vehicles using SPI Protocol

Avinash D. Kale, Shubhada S. Thakare, Dr. D. S. Chaudhari

***Abstract*—Tire pressure monitoring system (TPMS) is implemented in the vehicles to monitor the variations in tire pressure. The safety of driving improves as TPMS automatically detects the tire pressure, temperature in real-time and warns the drivers to take measures which prevents bursting of tire thereby avoiding the possibility of an accident. This paper discusses the design of vehicular tire pressure monitoring system using sensors. Also reviews the influence of tire pressure and temperature on traffic safety and environmental protection. In order to improve the functionality of TPMS the use of Serial Peripheral Interface (SPI) is suggested here. Finally, the performance of the system is tested and analyzed. The test results show that it meets the need of the practical application.**

***Index Terms*—Serial Peripheral Interface, Tire Pressure Monitoring System, Wireless Communication.**

I. Introduction

One of the prominent reasons for serious traffic accidents is bursting of tires. Hence the number of traffic accidents is also increasing along with the rapid growth in number of automobiles, which causes damages to vehicles as well as human body. Tire bursting is major concern for the drivers since it is very difficult to prevent. Research shows that tire burst is mainly caused by abnormal tire pressure and higher tire temperature [4]. Thus traffic accidents can be prevented if the tire pressure is regularly monitored during driving [7].

It is also observed that if the tire bursts at extremely high speed, the death rate is nearly 100%. Therefore the abnormal tire pressure affects the quality and the safety of automobile driving. Research studies show that if the tire pressure is maintained near to its standard value and pressure changes are discovered within time the possibility of tire-break can be avoided. Thus, many researchers and engineers are working on tire pressure monitoring system (TPMS). Currently, TPMS can be divided into two types: one is based on the wheel speed also called as indirect TPMS. In this system the difference between the speeds of the tires is compared through the Antilock Braking System (ABS) wheel speed sensor system of the vehicle for monitoring the tire pressure. The disadvantage of this system is that it cannot work if two tires are under-inflated and vehicle is moving with a speed above 100 km [8]. Hence this system works only when the wheels speed is up to a certain margin. The other is based on the pressure sensor also called as direct-TPMS. This system makes use of pressure sensor which installed in each tire to measure the tire pressure directly and displays and monitors the pressure of each tire [1]. According to the Transportation, Recall Enhancement, Accountability and Documentation (TREAD) Act passed by US Congress in 2008, it is necessary for all automobile manufacturers to install this tire pressure monitoring system in their vehicles produced or sold in the United States [9].

Avinash Kale, Department of Electronics and Telecommunication Engg., Government College of Engineering, Amravati., (e-mail: kale.avinash@gcoea.ac.in). Amravati, Maharashtra, India.

Shubhada Thakare, Department of Electronics and Telecommunication Engg., Government College of Engineering, Amravati., (e-mail: thakare.shubhada@gcoea.ac.in). Amravati, Maharashtra, India.

Dr. D. S. Chaudhari, Department of Electronics and Telecommunication Engg. Government College of Engineering, Amravati., (e-mail: chaudhari.devendra@gcoea.ac.in). Amravati, Maharashtra, India.

II. Experimental Setup

The system proposed here is Direct-TPMS. A direct TPMS mainly composed by two sections i.e. the transmitter module also called as pressure monitoring module and the receiver module. Pressure monitor module contains pressure sensor, temperature sensor, microcontroller unit and radio frequency transceiver chip. The receiver module contains microcontroller unit, RF transceiver chip, LCD display and the buzzer circuit. The TPMS systems works at different frequencies like 2.48, 3.15 or 4.33 GHz. The system proposed in this paper uses 2.48 GHz coming under ISM (Industrial, Scientific and Medical) band because this frequency is freely available. In order to avoid interference due to noise, frequency shift keying, Cyclic Redundancy Check (CRC) or Manchester Coding scheme can be used [1]. Fig. 1 shows the generalized system structure for TPMS.

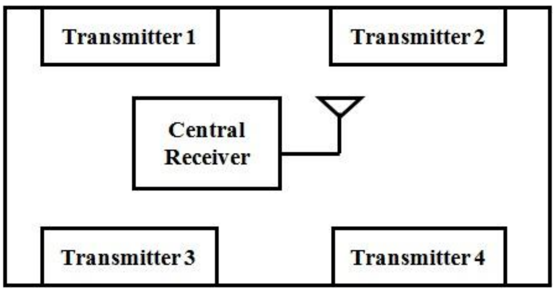

Fig.1 System structure showing a central receiver and transmitter installed in each tire

TPMS uses the pressure sensor to monitor the tire pressure in the automobile, and then transmits the observed value through the transmitter module, while receiver module receives the pressure information. When the pressure value is higher than or lower than the permissible normal range, the system sends out warning signal to the driver. The wireless transceiver module which transmits or receives radio-frequency signals is interfaced with microcontroller unit using Serial Peripheral Interface (SPI) bus.

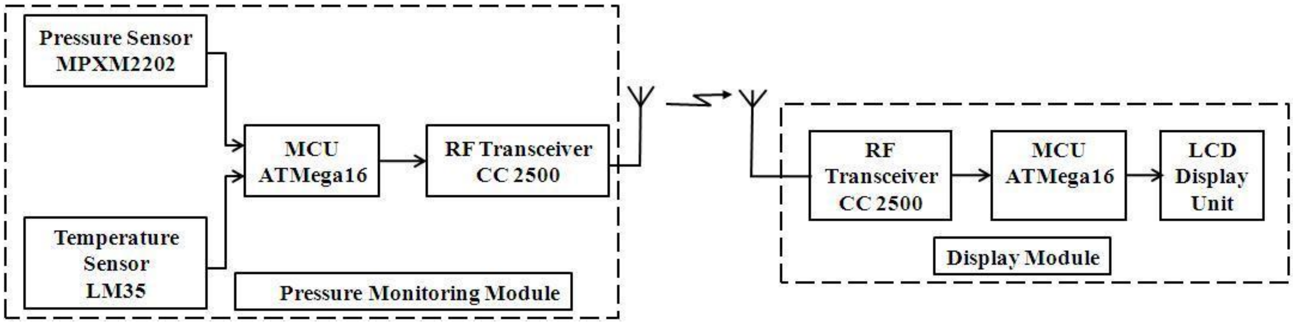

Fig. 2 Transmitter and receiver modules in TPMS

The tire pressure monitoring module or transmitter module is composed of MPXM2202 pressure sensor, LM 35 temperature sensor and the ATMega16 microcontroller. The pressure sensor MPXM2202 is responsible of monitoring tire pressure and temperature is measured by LM 35. The ATMega16 chip is used as the controller for tire pressure monitoring module. It receives the signal from pressure sensor and transmits the data to the host receiver via wireless RF communication. While designing the tire pressure monitoring module small size and low power consumption are the major issues. Fig. 2 shows the transmitter and receiver modules in TPMS.

A. Sensors

In this system MPXM 2202 is used for measuring tire pressure. MPXM2202 is a Silicon Piezoresistive pressure sensor providing a highly accurate and linear voltage output directly proportional to the applied pressure. The sensor is a single, monolithic silicon diaphragm with the strain gauge and a thin–film resistor network integrated on chip. The chip can measure tire pressure up to 200 kPa and is temperature compensated over 0 to 85°C. [6]

B. ATMega16 MCU

In this system ATMega16 is used as microcontroller unit because it supports Serial Peripheral Interface (SPI) protocol and has built in analog to digital converter. In built ADC converts the analog voltage variations coming from sensors into equivalent digital value. Also this microcontroller requires low power for its operation which is necessary for low power system designing [3] [4]. AtMega16 is interfaced with RF transceiver that can transmit digital data as far as 30 meters.

C. RF Transceiver

In the system, the major issue is how effectively the wireless radio frequency signal is transmitted because the RF transmission consumes most of the power [5]. Thus, when choosing a wireless radio frequency chip, power consumption is major issue along with the transmission bandwidth. In this design the IC CC2500 is used as radio frequency transceiver. It is a low-cost 2.4 GHz transceiver designed for very low-power wireless applications. The circuit can be used for the frequency range of 2400 to 2483.5 MHz i.e. ISM frequency band with the help of an onboard antenna. The biggest advantage of using this frequency is that it does not require license from government and this frequency is freely available. This chip is mainly selected because the main operating parameters and the transmit/receive FIFO register of CC2500 can be controlled via an SPI interface. It can transmit and receive the data in range of 30 meters without requiring any external antenna. In a typical system, the CC2500 will be used together with a microcontroller and a few additional passive components. Besides, it integrates a low-power PLL RF transmitter and voltage controlled oscillator, can modulate and transmit digital signals. It also supports FSK and ASK modulation modes. This RF transceiver also supports Manchester Coding which helps to improve the noise immunity. [1]

D. Warning system

A buzzer circuit can be interfaced with the receiver or master module along with the LCD display in order to alert the driver regarding the ups and downs in the pressure of the tire. The LCD display indicates the real time values of the tire pressure. Whenever the pressure value exceeds the predetermined values in any one of the tires, the buzzer circuit gets activated. Accordingly the driver can take the corrective action.

III. SERIAL PERIPHERAL INTERFACE (SPI)

In this design of tire pressure monitoring system SPI protocol is used to communicate between the microcontroller unit and radio frequency transceiver module. Data is exchanged between transmitter and receiver sections by using SPI. This protocol is mainly used because it allows serial communication between two or more devices at a high speed up to 10 Mbps. It is reasonably easy to implement as it is only 4 wired bus [1] [5].

In SPI is also called as 4 wired protocol. The MOSI (Master Out Slave In) and MISO (Master In Slave Out) lines transfer the data to and fro between the microcontroller unit and RF transceiver module. SCK (Serial Clock) line provides clock for synchronization between transmitter and receiver because data transfer depends on clock. The last line CS (Chip Select) is used for selecting the slave device [5]. Fig. 3 shows connections between microcontroller and RF receiver.

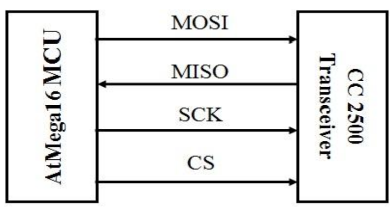

Fig. 3 Connection diagram for SPI Interface

IV. Analysis Of The System Performance

All the functions of the developed TPMS are tested for high pressure as well as low pressure situation. The system has good measurement accuracy and it can properly warn abnormal states well within in time and rightly. The whole performance is quite good.

Fig. 4 represents the data acquired in the form of plots showing relation between applied pressure in kPa and output sensor voltage in mV at different values of and supply voltages at 32^{o}C.

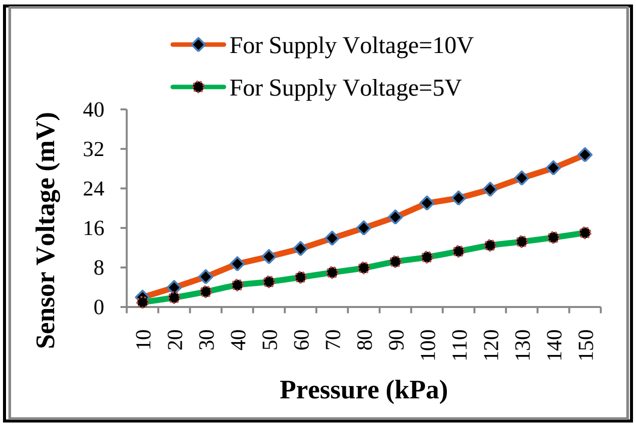

Fig. 4 Applied Pressure Vs Output Sensor Voltage

The output voltage of sensor depends upon offset voltage, pressure applied and sensitivity of sensor.

$$V_{out} = V_{off} + [Sensitivity * P]$$

Where V_{out} = Output voltage in mV
V_{off} = Offset voltage in mV
P = Pressure applied in kPa

Offset voltage is the voltage obtained at the output of sensor when input pressure applied is 0 kPa. Sensitivity is the ratio of change in output voltage with respect to change in pressure and it is measured in mV/kPa.

$$Sensitivity = \Delta V / \Delta P \qquad (mV/kPa)$$

For MPXM2202 pressure sensor used in this system the sensitivity is found to be 0.091 mV/kPa and offset voltage is ±1 mV at 32^{o}C when sensor is supplied with 5 V. This sensitivity is supply voltage dependant; hence sensitivity changes to 0.177 mV/kPa and offset voltage to ±2 mV when sensor is supplied with 10 V. The full scale voltage span of MPXM2202 is 40 mV and its linearity may vary up to 1 % of full scale voltage. Hence glitches or overshoots are observed at some points on the graph.

V. Conclusions

In recent years, TPMS is emerging as major part in the research of vehicle safety system. This paper proposes a Direct TPMS which based on the wireless sensors technology and also suggest the use of SPI protocol to improvise TPMS. Further, the system can be expanded to send a warning signal to the ABS control unit which will generate a control signal to apply brakes in order to achieve an automatic emergency braking. Also, research can be carried to reduce the power consumption of sensors used in the present system so that the system becomes more efficient. The tire pressure monitoring systems based on wireless sensor technology discussed here can also be used in wide range of applications.

References

[1] Y. Shiming, T. Jianbin, Hong Q., C. Chengrong, "Wireless Communication Based Tire Pressure Monitoring System," 1-4244-1312-5/07.
[2] I. H. Ho, J. M. Chung, H. C. Chen, H. W. Chiu, "A Battery-less Tire Pressure Monitoring System," 978-1-4244-2517-4/09.
[3] H. Wang, S. Yu , Y. Haung, Y. Pu, "Wireless Communication of Tire Pressure Intelligent Monitoring System Based on Sensor Networks Technology,", International Conference on Intelligent Control and Automation 2006.
[4] L. Yueming , H. Binghua, S. Jianchun, Y. Yuan, "Design and Implementation of TPMS Based on Wireless Sensor Network,", International Conference on Intelligent System Design and Engineering Application, 2010.
[5] F. Leens, "An introduction to I2C and SPI Protocol," IEEE Instrumentation and Measurement Magazine, 2009.
[6] L. Liu, X. Zhou, "Design of Intelligent Tire Safety Pre-alarm System Based on ARM9" International Conference on Informatics, 2010.
[7] M. Shao, W. Guo, "Tire Pressure Monitoring System," 978-1-4244-9439-2/11.
[8] J. Zhang, Q. Liu, Y. Zhong, "A Tire Pressure Monitoring System Based on Wireless Sensor Networks Technology," International Conference on Multi media and Information Technology, 2008.
[9] B. Fleming, "Tire Pressure-Monitoring Systems Rollout," IEEE Vehicular Technology Magazine, 2009.
[10] M. Kowaleski, "Monitoring and Managing Tire Pressure," IEEE Potentials, 0278-6648/04.
[11] Z. X. Wang, Y. Xu, G. J. Wang, "Design and Implementation of Tire Monitoring System Based on Zigbee", 978-1-4244-09.
[12] Q. Zhang, B. Liu, "Design of Tire Pressure Monitoring System Based on Resonance Frequency Method," IEEE/ASME International Conference on Advanced Intelligent Mechatronics, 2009.
[13] Dixon B. , V. Kalinin, J. Beckley, R. Lohr, "A Second Generation In-Car Tire Pressure Monitoring System Based on Wireless Passive SAW Sensors," 1-4244-0074-0/06.
[14] S. Yarnamoto, O. Nakao, H. Nishimura, "Touch Mode Capacitive Pressure Sensor for Passive Tire Monitoring System". 0-7803-7454-1/02.

Avinash Kale received the bachelor's degree in Electronics and Telecommunication engineering from SSGM College of Engineering, Shegaon, Maharashtra, India and currently pursuing M. Tech in Electronic System and Communication from Govt. College of Engineering, Amravati, Maharashtra, India.

Shubhada Thakare received the bachelor's and master's degree from Amravati University. Currently she is an Assistant Professor at Government College of Engineering, Amravati, Maharashtra, India with over 13 years of experience in teaching field. Her current areas of research are VLSI and Embedded Systems.

Devendra Chaudhari obtained BE, ME, from Marathwada University, Aurangabad and PhD from Indian Institute of Technology, Bombay, Mumbai. He has been engaged in teaching, research for period of about 25 years. Presently he is working as Head, Department of Electronics and Telecommunication Engineering at Government College of Engineering, Amravati. Dr. Chaudhari published research papers and presented papers in international conferences abroad at Seattle, USA and Austria, Europe. His present research and teaching interests are in the field of Biomedical Engineering, Digital Signal Processing and Analogue Integrated Circuits.