ISBN 978-967-2817-62-8

8
TIRE PRESSURE MONITORING SYSTEM

Muhammad Hafiz Mohamad Abdul Wahab, Ruzairi Abdul Rahim, Mohd. Fadzli Abdul Shaib, Mohamad Hafis Izran Ishak, Mohamed Sultan Mohamed Ali, Herman Wahid, Khairul Hamimah Abas, Juliza Jamaluddin, Tee Kian Sek

8.1 INTRODUCTION

Tire pressure plays an important role in the safety and fuel consumption considerations of automobiles. Vehicles moving with low tire pressure will consume more fuel. Leakage of air from tire, if not detected, can cause serious problems during running of vehicle. The proposed TPMS is designed keeping these vital considerations in view. This system can be integrated in the On-Board Diagnostic (OBD) system of automobiles. There are two basic methods to measure tire pressure; direct and indirect [1]. The direct technique is implemented. Numerous patents and designs have been introduced for tire pressure measurement. These designs recognize the importance of tire pressure measurement. Many companies nowadays are manufacturing TPMS with the pressure measuring unit mounted to the valve stem inside the tire (onto the inner side of rim). This requires modification to the tire. To change the electronic unit or its battery (in case of malfunction or battery replacement) the tire has to be opened. Moreover, the units must have casing strong enough to avoid damage to the units in case of tire burst. Also, different vehicles use different tires and manufacturing a single unit that matches requirement of all tires is a dilemma.

A blowout occurs when a flat tire is so severely damaged that immediately loses all air pressure and causes a driver to lose control, which is why it is one of the top causes of car accidents. Most car accident lawyers know that catastrophic and fatal big rig truck accidents are often the result of a major tire blowout. Indeed, all of us have heard about defective tires in the news; but many of the tires, even though defectively designed, might not have blown out if they were properly inflated. This is no excuse for a tire manufacturer. This section will describe some related projects done by other researcher and some news regarding cases of tire burst that cause car accident.

8.2 THEORY

8.2.1 Hardware Requirement

In making of these projects there is some hardware required to make sure the system working properly.

A. OMRON E8CC 10 Pressure Sensor:
It is a general-purpose pressure sensor which can measure up to 10 bar gauge pressure. A special nozzle was constructed that could fit onto the stem of tire from one end and also to the OMRON sensor on the other end. It had a small metallic rod attached at the center that would hit the stem for air flow towards the sensor. When the nozzle is screwed on the valve stem, first few turns would make the unit air tight to avoid air leakage. Later turns cause the rod in nozzle to press the stem button for air flow and the pressure switch also activates indicating presence of tire. Figure 8.1 shows valve stem and sensor connection using special nozzle

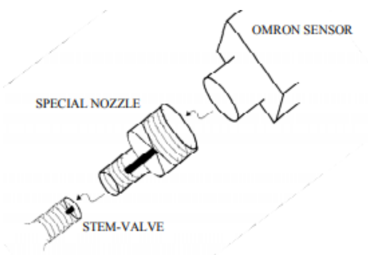

Figure 8.1: Valve stem and sensor connection using special nozzle

B. Power Supply:
Long life battery of +12volts is required for each transmitting unit on tire. In case of battery die out, it can be easily replaced.

C. Microcontroller:
For the transmitting unit, any small general-purpose controller

ISBN 978-967-2817-62-8

can be used. It must have internal timer, ADC channels (at least two), UART, sleep option and wake-up upon timer interrupt. For ease, PIC16F688 was used. For receiver side, any controller having sufficient I/O pins to control LCD and keypad and UART is required. PIC18F452 was used for implementation and testing of system.

D. RF Transmitter and receiver:
Telecontrolli's RTFQ2 and RRFQ2 have been used. These modules can effectively send/receive serial data at 9600bits/sec rate.

E. Battery used:
Any +12volts battery can be used which has a long life. Modern TPMS use lithium batteries with design life of 10 years. To exhibit the working of system, available cell (23A 12v alkaline battery) was used.

8.2.2 Operation of System

A. Transmitting unit:

Each tire of the vehicle has a transmitting unit which is uniquely identified by the receiver through its ID. The unit can measure tire pressure whether the vehicle is still or in motion. The unit has a pressure sensor, pressure switch, signal conditioning unit, microcontroller, long life battery (+12volts) and RF transmitter. All units are switched ON and screwed to the stem-valve of tires. When the unit is screwed into the stem of tire, the pressure switch is activated. Pressure sensor can directly sense the air pressure of tire. Pressure of tire produces voltage at output terminal of sensor. Linear relationship exists between pressure and sensor's output voltage [6]. This voltage is provided to the signal conditioning unit which has a differential op amp amplifier. Output voltage from amplifier is provided to the built-in analog-to-digital conversion (ADC) channel of controller which produces and stores 8-bit data of tire pressure. It then sends packets serially (built-in UART) to the RF transmitter at 9600bits/sec baud rate.

The unit transmits 2 to 3 packets at a time in a particular sequence. If the pressure switch is active then first one packet of tire ID is sent followed by a packet containing tire pressure data. But if switch is inactive, then the second packet contains "Tire not available" information. Controller also counts the no. of packets sent. If 100 transmissions have been made then it will also send third packet in sequence containing information of battery status. Battery status is determined from another ADC channel of controller. Figure 8.2 shows format of packet.

START FLAG	SYSTEM ID	TYPE	INFORM-ATION	CHECK SUM	STOP FLAG
8-bit	6-bit	2-bit	8-bit	8-bit	8-bit

Figure 8.2: Packet format

Start and stop flags fields are 8-bit wide indicating start and end of packet. System ID must match system ID stored in receiver. This system ID is same for all transmitting units on the same vehicle but different for TPMS systems on other vehicles. Type field tells the information type.
00= tire ID, 01= tire pressure data, 10=battery status, 11=tire not available

Tire ID, tire pressure data, battery status and tire not available are all 8-bit information. Checksum is used for correct data reception. Packet is rejected by receiver if checksum doesn't match. Sequence of packet transmission is; first tire ID, second tire pressure data/tire not available and then battery status (if count of transmissions is 100). This packet sequence is sent wirelessly through RF transmitter. Then the controller goes into sleep mode (for power saving) for eight seconds. In this time remaining units transmit their packets using same principle. Although time needed to send three packets at 9600bits/sec is about 13 milli-seconds, 8 seconds delay is given so that two or more units don't transmit simultaneously or else collision of data may occur. Controller will wake up after 8 seconds (using internal timer interrupt), it will sense the pressure switch and the process is repeated. Refer to Figure 8.3 for operation flow of transmitting unit.

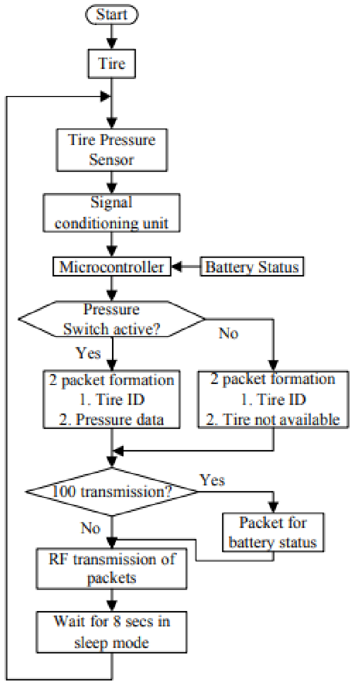

Figure 8.3: Operation flow of transmitting unit

B. Receiving Unit

There is a single on-board receiver unit for all four transmitting units. It consists of an RF receiver, microcontroller, LCD, keypad and power comes from battery of vehicle. It has a unique system ID. Upon power up it will initiate the LCD and keypad and then start receiving packets from the RF receiver. Controller will accept packets only in a particular sequence (same as transmitting unit). After receiving packets, it checks for errors using checksum field. If any error is detected in any packet, the controller will reject all packets coming from that tire and will wait to receive packets from next transmitting unit. Upon successful reception of packets from a tire, tire pressure and battery status are calculated using the information field byte. Controller uses predefined formulas for this purpose. It then displays tire pressure and battery status of all tires on the LCD and also stores them in its internal EEPROM. These values are real-time numeric values and precision is up to two decimal places (Figure 8.4).

ISBN 978-967-2817-62-8

If calculated tire pressure of any tire goes below the defined lower limit of pressure, warning screen is generated showing LOW TIRE PRESSURE along with tire number and buzzer becomes active. Similarly, if calculated tire pressure of any tire goes above the defined upper limit of pressure, warning screen is generated showing HIGH TIRE PRESSURE along with tire number and buzzer becomes active. Controller waits for user acknowledgment through keypad. Also, if the tire pressure changes abruptly and difference between new and old reading is more than 1psi (default value) then warning screen is generated showing ABRUPT CHANGE IN TIRE#1(say) .

The controller also displays three options to the user on LCD; change lower limit value, upper limit value and abrupt change in tire pressure value. So, the user can set these values according to wish or go with the default values. The maximum and minimum safe pressure level and the value of abnormal abrupt change are stored in three different locations in the EEPROM of controller. In our system psi (pounds per square inch) is the pressure unit and tire pressure value for vehicles can be easily stored in one byte of memory (less than 256 psi). The main reason to use EEPROM is that controller cannot change and store values in its ROM during operation as ROM is burned once only. RAM memory is volatile and if the system is turned off, the values will be erased and the user will have to enter these values again every time the system is started. But contents of EEPROM can be easily changed during controller operation by the controller itself

The three locations of EEPROM discussed are loaded with default values. E.g., the minimum tire pressure should be 25 psi and any value below 25 psi will generate warning. But what if the user wants a warning to be generated at 28 psi? Moreover, different tires have different pressure ratings and the default pressure values may be incorrect for that tire. Hence the user has been provided with a unique feature to adjust the system behavior according to tire specifications. Tire pressure specifications (max. and min. air pressure) are mentioned on the sidewall of tire. User must choose the safe range according to the specifications. Figure 8.4 shows the operating flow of receiving unit.

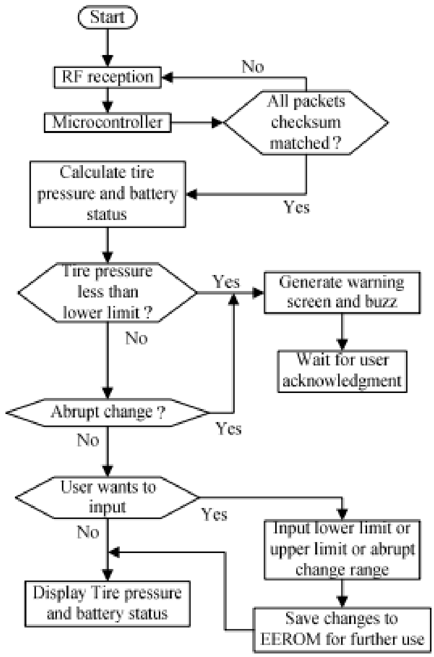

Figure 8.4: Operation flow of receiving unit

8.3 LITERATURE REVIEW

8.3.1 Tire Pressure Monitoring System with Wireless Communication

This is a project was done by Nouman Naim Hasan, Adeel Arif, Muhammad Hassam, Syed Shabeeh Ul Husnain, Usman Pervez from NED University of Engineering and Technology. The paper proposes a method to implement Tire Pressure Monitoring System (TPMS) in vehicles. TPMS measures the air pressure inside pneumatic tires of automobiles. The proposed TPMS has an electronic unit that directly screws onto the stem of tire. The unit includes a pressure sensor and switch, signal conditioning unit, microcontroller, RF transmitter and long-life battery. An onboard RF receiver communicates with the TPMS unit and displays real-time tire pressure of all tires as shown in Figure 8.5.

The unit can be easily detached and re-attached to the tire. Modification to the tire is not required. The system and each TPMS unit have unique ID code to prevent false data reception from neighboring

ISBN 978-967-2817-62-8

vehicles. Tire replacement or maintenance will not affect the system's working. Warning is generated whenever tire pressure crosses the maximum or minimum safe pressure level, or when it changes abruptly. This lower level and upper limit of tire pressure or safe range of abrupt change can be modified by user through the user interface. The system has been implemented on a car. It has given accurate results while proving to be user friendly.

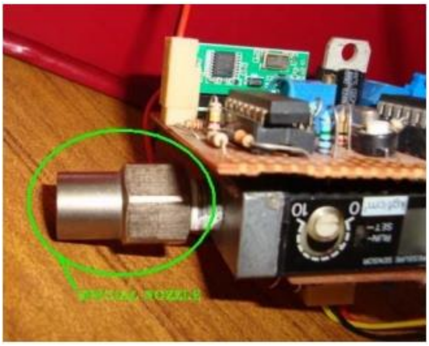

Figure 8.5: The implementation of the project

8.3.2 Wireless Tyre Pressure Monitoring System for Motor Vehicles

Wireless Tyre Pressure Monitoring System for Motor Vehicles (WTPMS) is a tyre pressure monitoring system used in any type of the vehicles. This technology involves two parts that is all tyres pressure monitoring system in motor vehicle and main board or display screen indicating status of all tyres pressure and intercommunication through wireless technology. In each tyre pressure monitoring set, there is a small kit consists of micro-controller, sound alarm, pressure sensor and battery. This small kit senses high and low air pressure inside the tyre and informs to main circuit mounted on the display screen. Because of which driver or rider will come to know the air pressure status of every tyre and can take appropriate action. The sound alarm introduced in small kit is to identify high pressure level; if air inside the tyre exceeds the defined level then sound alarm is generated. Light blinking facility is provided on the display screen to show low air pressure status of any tyre. This communication between main circuit (display screen) and every tyre kits is done through wireless medium which can be Wi-Fi or Bluetooth. The wireless charging is done to charge small tyre kit though vehicle has main battery backup or charging point inside the vehicle. To protect the tyre pressure kit from problem of overheating, cooling substance or cooling liquid is used as heat absorbent around the kit, which helps to maintain kit's long life. Due to use of such technology road accidents caused due to low or too much high air pressure of tyres can be avoided. The proposed technology gives information of all tyres' pressure to the user on the display screen, which minimizes human efforts to check air externally. Also cost on the air check instruments can be minimized due to this proposed work. Figure 8.6 shows the block diagram of proposed system.

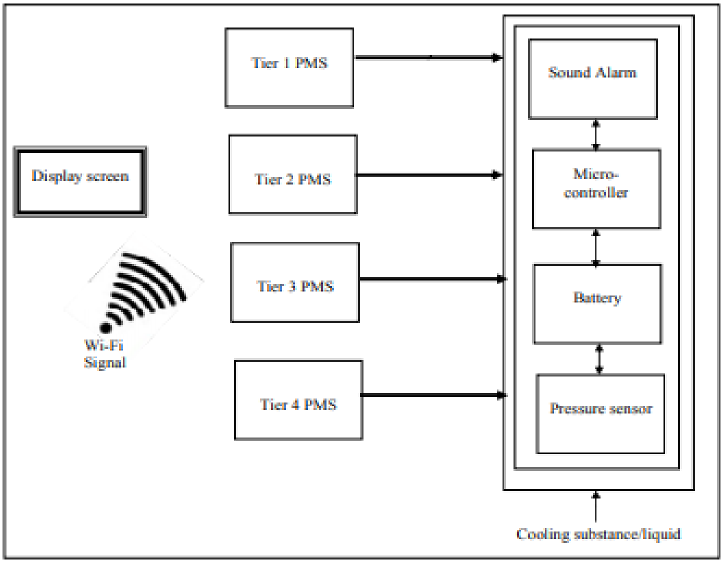

Figure 8.6: Complete Block diagram of proposed system.

8.3.3 Fully Printed and Flexible Carbon Nanotube Transistors Designed for Environmental Pressure Sensing and Aimed at Smart Tire Applications

As the sensor infrastructure needed to facilitate the internet-of-things (IoT) rapidly expands, printed electronics have been identified as a key approach for providing low-cost, ubiquitous sensor networks. In this work, it demonstrates the use of a fully printed carbon nanotube thin-film transistor (CNTTFT) for sensing environmental pressure over a large pressure range. The transconductance of the transistor was found to be directly and linearly correlated with environmental pressure with a sensitivity of 48.1 pS/PSI. it also demonstrates the capability of wirelessly transmitting the data measured by the pressure sensor from within an automobile tire using a simple Bluetooth module. Furthermore, they package the sensor, along with a material thickness sensor developed in previous work, for a fully printed smart tire sensor system capable of mapping tire pressure and tread depth differentials as shown in Figure 8.7.

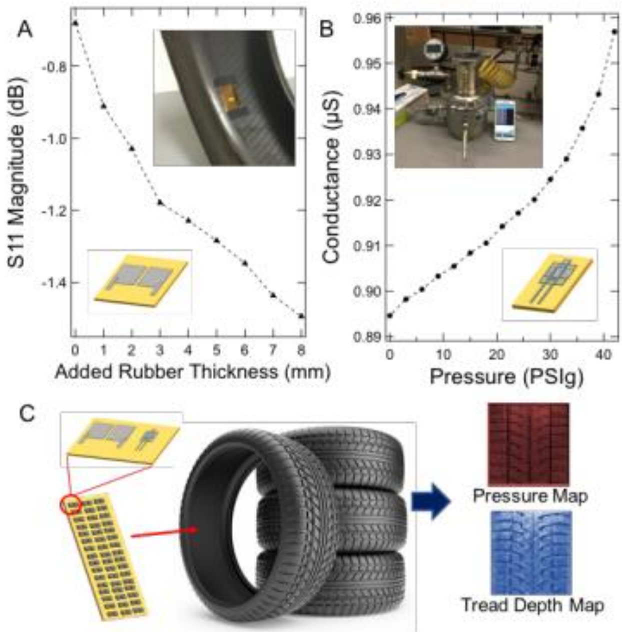

Figure 8.7: Operation of a fully printed, material thickness sensor (A) and a flexible Kapton pressure sensor (B) with a photograph during operation and device schematic cartoons as insets. (C) A cartoon schematic with hypothetical implementation of a fully printed and fully integrated tire monitoring system that would allow for pressure and tread depth mapping.

ISBN 978-967-2817-62-8

8.4 CONTRIBUTIONS

Table 8.1 shows several examples of cases for tire blowout.

Table 8.1: [4]-[8]

YEAR	TITLE & AUTHORS	REMARKS
27 Dec 2020	Woman, 21, escapes crash with serious injuries after tire blowout in Pasco County WFLA 8 On Your Side Staff	PASCO COUNTY, Fla. (WFLA) — A 21-year-old Ocoee woman was hospitalized in serious condition after a crash in Pasco County Sunday morning made her vehicle unrecognizable. The Florida Highway Patrol said the woman, who was not identified, was driving south on State Road 93 in the outside lane when her car suffered a tire blowout.
18 August 2018	Car tires explode, teenagers die Mohamed Farid Noh	KLUANG: A 15-year-old teenager died when the car he was traveling in with his family skidded before overturning due to a tire exploding at Kilometres 50.8 of the North-South Highway, southbound,
2 Mac 2019	MPV accident victims tire exploded critically Mohamed Farid Noh	KULAI: Three victims of an accident involving a multi -purpose vehicle (MPV) that skidded before overturning at kilometre 18.2 of the North -South Expressway (PLUS) southbound, here, at noon yesterday, were in critical condition and treated at the Intensive Care Unit (ICU), Hospital Sultanah Aminah (HSA), Johor Bahru.
31 Oct 2017	THE TRAGEDY OF THE KILLER TRUCK AND BUS	In December 2015, a teacher died in Kuantan because he was hit by a tire

	HEZERI SAMSURI	from a bauxite lorry that was torn off and bounced off his car. Earlier, 2012 saw two foreign tourists die because the bus they were traveling in skidded while getting off from Genting Highlands. The bus is believed to have brake problems.

8.5 CONCLUSION

In this design great emphasis has been made to make TPMS system user friendly and vehicle friendly. The system was implemented using the available hardware discussed above. Vehicle testing gave reliable and stable response. Compared to TPMS systems available in market, this system has its own advantages. The transmitting unit's size can be reduced if a pressure transducer is used instead of OMRON sensor which basically is a general-purpose sensor. Application Specific Integrated Circuit (ASIC) for the transmitting unit will greatly reduce size. Reduction in size will not affect working of system. And to increase possible no. of systems, the packet size can also be increased. These modifications can be made if this technique is to be launched as a product. Fig. 5 (a, b and c) are pictures of the realized system.

REFERENCES

[1] United Nations Economic Commission for Europe Informal document # 20 (53rd GRRF, 3-7 February 2003, Agenda Item 8) http://www.unece.org/trans/doc/2003/wp29grrf/TRANS-WP29-GRRF-53-20ebis.pdf

[2] Victor Mendez, Kevin J. Hawes. "Method and apparatus for tire pressure monitoring and for shared keyless entry control" U.S. Patent number: 5,463,374.

[3] Carl A. Fiorletta. "Tire pressure monitoring system" U.S. Patent number: 5,289,160.

[4] Stephen McClelland. "Remote tire pressure monitoring system" U.S.Patent number: 5,963,128.

[5] Sung Jin Jo, Chee Seong Chua. "Tire pressure monitoring system"U.S.

Patent number: 5,883,305.

[6] Datasheet of OMRON E8CC 10C http://www.ia.omron.com/data_pdf/data_sheet/e8cb_e8cc_dsheet_g wd071-e1-1.pdf

[7] Datasheet of RTFQ2 and RRFQ2 http://www.telecontrolli.com/risorse/download/schede-tecnicheprodotti/transmitters/131-rtfq2/download_it.html http://www.telecontrolli.com/risorse/download/schede-tecnicheprodotti/receivers/30-rrfq2/download_it.htm

ISBN 978-967-2817-62-8