FINAL YEAR PROJECT REPORT

"Tire Pressure Monitoring System"

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Abstract

We live in a world where numbers guide us to better outcomes and results. The numerical representations along with Artificial Intelligence have brought us new possibilities to make our life comfortable and safe. Safety in our road trips has always been an attraction to ambitious engineers. TPMS is one of such safety devices now being widely used all over the world.

Tire Pressure Monitoring System – TPMS, as the name suggests, monitors the tire pressure of a vehicles and displays the results on the dashboard along with alerts in case of a deviation from the set value. In this project we have tried to lower the cost and make the device versatile for different kinds of vehicles and environments. Our design can be used as a principle unit in many industries where pressure measurement is vital and need frequent results.

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Chapter 1

1.1 Introduction

A **tire pressure monitoring system** (**TPMS**) is an electronic system designed to monitor the air pressure inside the pneumatic tires on various types of vehicles. TPMS report real-time tire-pressure information to the driver of the vehicle, either via a gauge, a pictogram display, or a simple low-pressure warning light. TPMS can be divided into two different types — direct (dTPMS) and indirect (iTPMS). TPMS are provided both at an OEM (factory) level as well as an aftermarket solution.

1.2 History

Due to the significant influence tire pressure has on vehicle safety and efficiency, TPMS was first adopted widely by the European market as an optional feature for luxury passenger vehicles in the 1980s. The first passenger vehicle to adopt tire-pressure monitoring (TPM) was the Porsche 959 in 1986, using a hollow spoke wheel system developed by PSK. In 1996 Renault used the Michelin PAX system for the Scenic and in 1999 the PSA Peugeot Citroën decided to adopt TPM as a standard feature on the Peugeot 607. The following year (2000), Renault launched the Laguna II, the first high volume mid-size passenger vehicle in the world to be equipped with TPM as a standard feature.

In the United States, the Firestone recall in the late 1990s (which was linked to more than 100 deaths from rollovers following tire tread-separation), pushed the Clinton administration to legislate the TREAD Act. The Act mandated the use of a suitable TPMS technology in all light motor vehicles (under 10,000 pounds), to help alert drivers of severe under-inflation events. This act affects all light motor vehicles sold after September 1, 2007. Phase-in started in October 2005 at 20%, and reached 100% for models produced after September 2007. In the United States, as of 2008 and the European Union, as of November 1, 2012, all new passenger car models (M1) must be equipped with a TPMS. For N1 vehicles, TPMS are not mandatory, but if a TPMS is fitted, it must comply with the regulation.

After the Tread Act was passed, many companies responded to the new market opportunity by releasing TPMS products that use an obvious means of getting tire pressure and temperature data across a vehicle's rotating wheel-chassis boundary — battery-powered radio transmitter wheel modules.

The introduction of run-flat tires and emergency spare tires by several tire and vehicle manufacturers has motivated to make at least some basic TPMS mandatory when using run flat tires. With run flat tires, the driver will most likely not notice that a tire is running flat, hence the so-called "run flat warning systems" were introduced. These are most often first generation, purely roll-radius based iTPMS, which ensure that run-flat tires are not used beyond their limitations, usually 80 km/h and 80 km driving distance.

In recent years, several advancements have been made in the TPMS market. New developments aim at battery-less systems, such as those developed by VisiTyre TPMS, and advanced iTPMS.

STE Engineering has introduced an energy efficient wireless sensor device based on a technology called SPX (Short Pulse Technology) which integrates a hybrid ceramic circuit inside the body of a standard tire stem.

The TPMS market has progressed as well. Indirect TPMS are able to detect under-inflation through combined use of roll radius and spectrum analysis and hence four-wheel monitoring has become feasible. With this breakthrough, meeting the legal requirements is possible also with iTPMS such as the Tire Pressure Indicator by NIRA Dynamics AB.

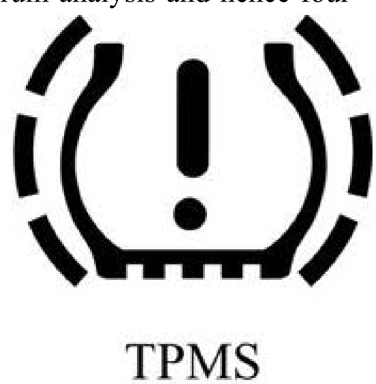

Figure 1 TPMS Warning Logo

TPI by NIRA was the first iTPMS to comply with the United States regulation FMVSS 138, as it was released with the Audi A6 for the 2009 model year. Since then, it has been introduced in various VW and Audi models and is in use in the United States in more than 250,000 vehicles. NIRA had their system TPI successfully tested by certification organization TÜV Süd Automotive for compliance with the future European legislation ECE-R64.

1.3 Importance

1.3.1 Accidents

Under-inflated tires lead to tread separation and tire failure, resulting in 40,000 accidents, 33,000 injuries and over 650 deaths per year. Further, tires properly inflated add greater stability, handling and braking efficiencies and provide greater safety for the driver, the vehicle, the loads and others on the road. 9% of all road accidents involving fatalities are attributable to tire under-inflation.

1.3.2 Environment

Under-inflated tires, as estimated by the Department of Transportation, release over 57.5 billion pounds of unnecessary carbon-monoxide pollutants into the atmosphere each year in the United States alone. So we see there is a great influence of tire inflation on environment for whole world. As we know ozone layer is also depleted by chlorofloro-carbons and carbon monoxide. The European Union concludes that tire under-inflation today is responsible for over 20 million liters of unnecessarily-burned fuel, dumping over 2 million tonnes of CO_2 into the atmosphere.

1.3.4 Fuel Consumption

According to the GITI, for every 10% of under-inflation on each tire on a vehicle, a 1% reduction in fuel economy will occur. In the United States alone, the Department of Transportation estimates that under inflated tires waste 2 billion US gallons (7,600,000 m^3) of fuel each year.

1.3.5 Tire Life

Under inflated tires is the #1 cause of tire failure and contribute to tire disintegration, heat buildup, ply separation and sidewall/casing breakdowns. Further, a difference of 10 lbs. in pressure on a set of duals literally drags the lower pressured tire 13 feet per mile. Moreover, running a tire even briefly on inadequate pressure breaks down the casing and prevents the ability to retread. It is important to note that not all sudden tire failures are caused by under-inflation. Structural damages caused, for example, by hitting sharp curbs or potholes, can also lead to sudden tire failures, even a certain time after the damaging incident. These cannot be proactively detected by any TPMS. The European Union reports that an average under-inflation of 40 kPa produces an increase of fuel consumption of 2% and a decrease of tire life of 25%. The European Union concludes that tire under-inflation today is responsible for 200 million tires being prematurely wasted worldwide.

1.3.6 Engine Life

Due to inflated tires engine has to exert more power to gain the normal speed so more working inside the engine and less the output. This decreases engine's life and finally increases cost of life.

1.4 Targets

- Avoiding traffic accidents due to under-inflated tires by early recognition of the malfunction of tires
- Reducing CO_2 emission and reducing tire abrasion by an optimal inflation

1.5 Basics of TPMS

There are two types of TPMS providing to customers. These types are describes as follows

1.5.1 Indirect TPMS

Indirect iTPMS do not use physical pressure sensors but measure air pressures by monitoring individual wheel rotational speeds and other signals available outside of the tire itself. First generation iTPMS systems utilize the effect that an under-inflated tire has a slightly smaller diameter (and hence higher angular velocity) than a correctly inflated one. These differences are measurable through the wheel speed sensors of ABS/ESC systems. Second generation iTPMS can also detect simultaneous under-inflation in up to all four tires using spectrum analysis of individual wheels, which can be realized in software using advanced signal processing techniques. The spectrum analysis is based on the principle that certain eigen forms and frequencies of the tire/wheel assembly are highly sensitive to the inflation pressure. These oscillations can hence be monitored through advanced signal processing of the wheel speed signals. Current iTPMS consist of software modules being integrated into the ABS/ESC units.

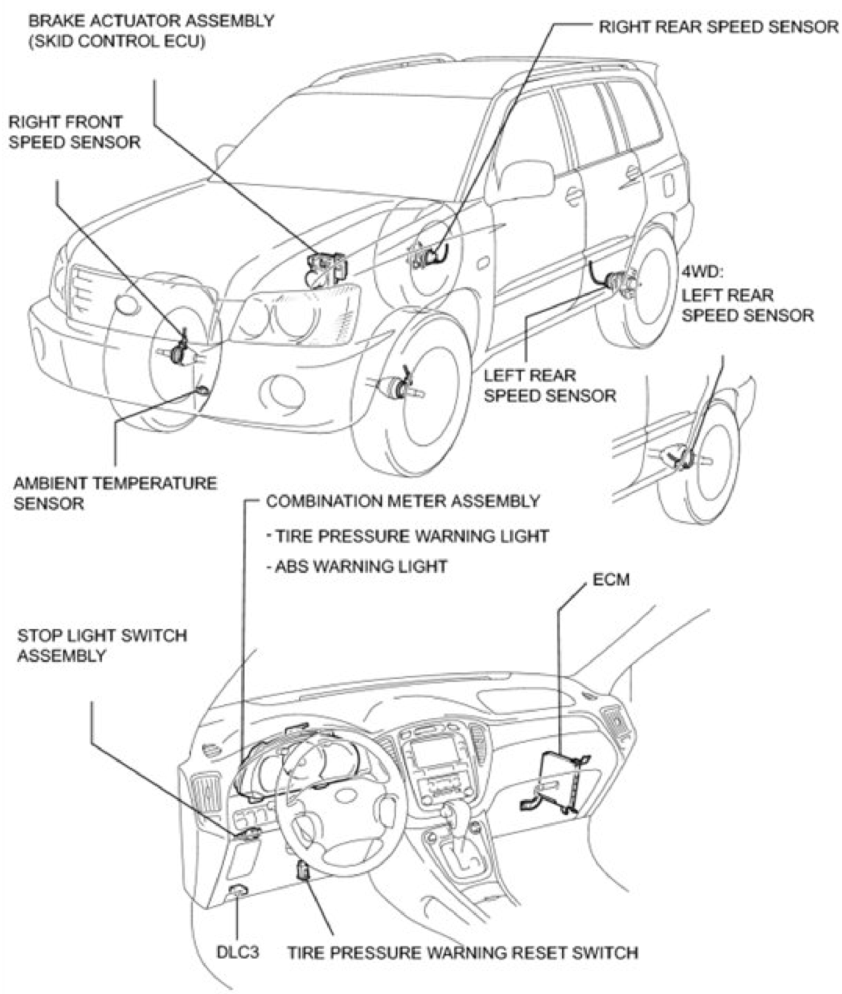

Figure 2 Typical functionality of Indirect TPMS

iTPMS cannot measure or display absolute pressure values, they are relative by nature and have to be reset by the driver once the tires are checked and all pressures adjusted correctly. The reset is normally done either by a physical button or in a menu of the on-board computer. iTPMS are, compared to dTPMS, more sensitive to the influences of different tires and external influences like road surfaces and driving speed or style. The reset procedure, followed by an automatic learning phase of typically 20 to 60 minutes of driving under which the iTPMS learns and stores the reference parameters before it becomes fully active, cancels out many, but not all of these. As iTPMS do not involve any additional hardware, spare parts, electronic or toxic waste as well as service whatsoever (beyond the regular reset), they are regarded as easy to handle and very customer friendly.

According to Nira, based on their request to TÜV SÜD to do a pre-test according to similar requirements of the EU legislation, the iTPMS system passed that pre-test.However, the full test procedure as required by the EU regulation, completed by the regulatory body assigned to make the homologation, has not yet been done. Manufacturers like Dunlop Tech also claim their products to fulfill the regulations.

1.5.2 Direct TPMS

Direct TPMS employ pressure sensors on each tire, either internal or external. The sensors physically measure the tire pressure in each tire and report it to the vehicle's instrument cluster or a corresponding monitor, sometimes also the temperature inside the tire. These systems can identify under-inflation in any combination, be it one tire or all four, simultaneously. Although the systems vary in transmitting options, many TPMS products (both OEM and aftermarket solutions) can display real time tire pressures at each location monitored whether the vehicle is moving or parked. There are many different solutions but all of them have to face the problems of limited battery lifetime and exposure to tough environments. If the sensors are mounted on the outside of the wheel, which is the case for some aftermarket systems, they are in danger of mechanical damage, aggressive fluids and other substances as well as theft. If they are mounted on the inside of the rim, they are no longer easily accessible for service like battery change and additionally, the RF communication has to overcome the damping effects of the tire which additionally increases the need for energy.

A direct TPMS sensor consists of following main functions requiring only a few external components — *e.g.*, battery, housing, PCB — to get the sensor module that is mounted to the valve stem inside the tire:

- pressure sensor;
- analog-digital converter;
- microcontroller;
- system controller;
- oscillator;
- radio frequency transmitter;
- low frequency receiver, and
- voltage regulator (battery management).

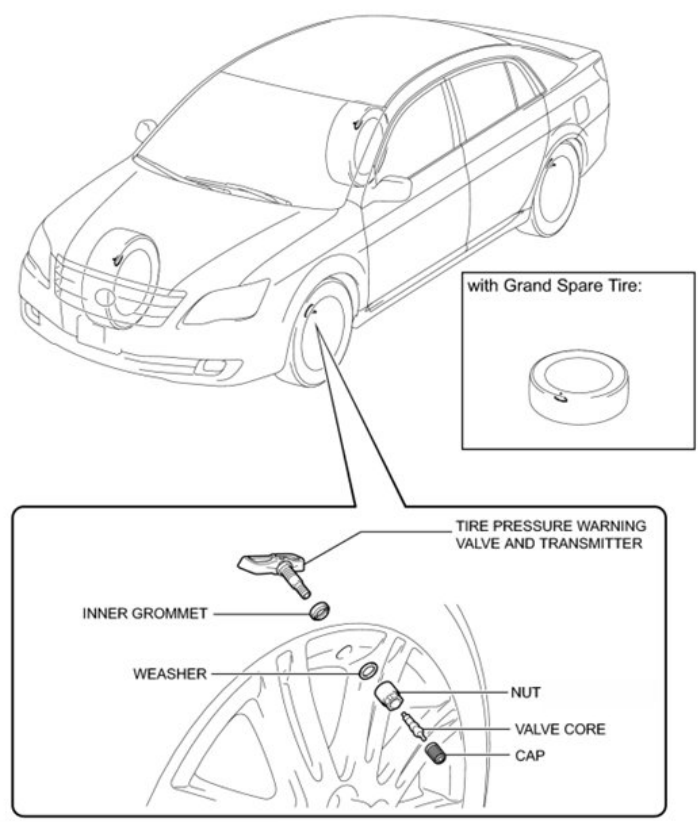

Figure 3 Typical functionality of Direct TPMS

Most originally fitted dTPMS have the sensors mounted on the inside of the rims and the batteries are not exchangeable. With a battery change then meaning that the whole sensor will have to be replaced and the exchange being possible only with the tires dismounted, the lifetime of the battery becomes a crucial parameter. To save energy and prolong battery life, many dTPMS sensors hence do not transmit information during standstill at all or apply a complex and expensive two-way communication which enables an active wake-up of the sensor by the vehicle.

For dTPMS to work properly, they need to recognize the sensor positions and have to ignore the signals from other vehicles' sensors. There are hence numerous tools and procedures to make the dTPMS "learn" or "re-learn" this information, some of them can be carried out by the driver, others need to be done by the workshops or even require special electronic tools. The cost and variety of spare parts, procedures and tools has led to much trouble and confusion both for customers and workshops.

1.5.3 Direct vs. Indirect

As we see direct method is quite user friendly and it does not requires any further calculations to know the tire pressure. It simply tells the right value of air pressure in the tire. We are making direct type of TPMS in this project.

1.5 Future Prospects

Pressure sensors provided in world lead us to calculations of further future prospects of our project. One can do many things from this type of TPMS just by using the different types of pressure sensors. You just change the sensor and enter your normal pressure and you can measure pressure of any environment. Like you can place it in your room to measure room pressure and may other things like boiler, pressure cooker and any industrial unit. We can do many other things like measurements of speed and acceleration and light movements (by using very sensitive sensors

1.5.1 Measuring Speed and Acceleration

We can also measure speed and acceleration of any object by using this type of TPMS. Place it in front of moving object and by qualitative measurements and measuring pressure at known speed we can build up ratios of speed and according pressure. In the same way we can also measure acceleration.

As well as by using ultra-sensitive pressure sensors we can detect movement of products in a close environment.