NIRA DYNAMICS

TPI

– Advanced Indirect

Tire Pressure Monitoring

Executive Summary

- 75% of all tire failures are preceded by under-inflation or slow leakages and tire problems are the third most common breakdown for passenger vehicles.
- Fuel consumption increases by 3% and tire lifetime decreases by 15% for every 0.2 bar under-inflation.
- Approximately 20% of all passenger cars have under-inflated tires by up to 40%.

TPI, from NIRA Dynamics AB, is an indirect tire pressure monitoring system that ensures that these problems are avoided.

With TPI the driver will be alerted if any of the tires is under-inflated long before the tire breaks down. This increases safety. It also lowers the environmental impact and lowers the driver's costs thanks to the reduced tire wear and reduced fuel consumption when the tires are correctly inflated.

TPI is a software solution that detects changes in the tire inflation pressure using the wheel speed signals. Since TPI does not require any extra sensors it is very cost effective. TPI is easy to integrate in different target systems since the same software kernel can be used for different processors and target systems. Further, since TPI is a software solution and does not rely on any wheel-mounted, battery-powered pressure sensors and radio frequency transmitters and receivers it requires a minimum of maintenance and continues to function also if the tires or the complete wheels are replaced.

TPI has performance comparable to a sensor-based tire pressure monitoring system, but to a significantly lower total cost. TPI is capable of detecting pressure drops in one, two, three, and four tires and is robust against surface changes, load variations and driving styles. TPI also automatically adjusts to different types of tires: summer tires, all season tires, non-studded and studded winter tires, run-flat tires, etc.

TPI meets the FMVSS 138 requirements for cars, light trucks, and SUVs sold in USA from September 1, 2007.

1. NIRA Dynamics AB

NIRA Dynamics AB is a privately owned, limited Swedish company specialized on software solutions for different vehicle dynamics and active safety applications such as tire pressure monitoring, tire-road friction monitoring and traction control.

NIRA Dynamics AB's customers are vehicle manufacturers and tier 1 suppliers. Our business idea is to license in-house developed software components and to offer engineering services related to the company's products.

2. TPI

2.1 Basic Functionality

TPI is a software-based, indirect tire pressure monitoring system (TPMS). TPI uses advanced signal processing and sensor data fusion techniques applied to the wheel speed signals and other information sources available in the vehicle to monitor the inflation pressures in all four tires and warn if one or more tires have too low pressure.

TPI can detect and isolate under-inflation in one to four tires simultaneously. With TPI you can thus use a graphical display of the type shown into warn the driver of under-inflation and point out the faulty tire(s). This makes TPI the most advanced indirect TPMS on the market.

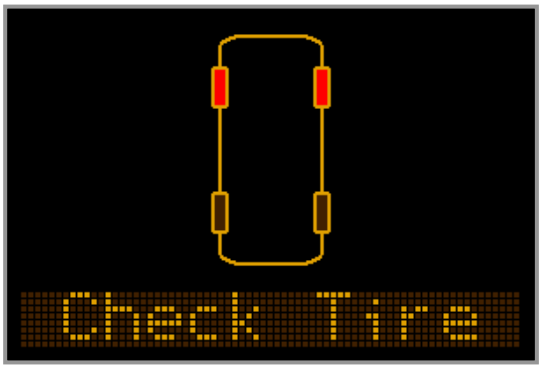

Figure 1 Example of a graphical TPI display

2.2 Calibration

TPI detects changes in tire inflation pressure and issues an alarm if this drops below a specified limit. Since TPI is an indirect tire pressure monitoring system it does not measure the absolute value of the tire inflation pressure, and hence only *changes* in the tire inflation pressure can be detected. The changes are measured relative to the correct (cold) inflation pressure, which is learned during an initial *calibration* phase. If the tire inflation pressure drops below a specified limit, compared to the pressure at calibration, the system issues an alarm.

The driver is responsible for inflating the tires to the correct (cold) inflation pressure. The system cannot judge by itself whether the tires have the correct inflation pressure when the calibration is initiated.

Depending on the user interface design the driver (or a technician) initiates calibration either by pressing a calibration button or by selecting calibration from a menu in the display system of the vehicle. The driver should initiate calibration whenever the tire inflation pressure is changed or when the tires have been changed or rotated compared to their original positions.

To get a fully calibrated system it is required that the vehicle is driven in different speeds. There is no need for special actions or manoeuvres by the driver, the system will calibrate automatically during normal varied driving. The system needs approximately five minutes of normal driving to become active, i.e. the system is able to detect pressure drops after approximately five minutes. After 20 minutes the system is able to detect pressure drops of 25% in up to all four tires. To complete calibration and reach full performance, the system needs approximately one to two hours of normal driving, but this is dependent on driving style and on how the speed is varied.

The calibration does not have to be completed in one driving cycle. If the engine is turned off during calibration the system will write the current calibration data to a non-volatile memory and read this out and restart calibration when the engine is restarted.

2.3 Detection Performance

TPI meets the performance requirements in FMVSS 138 published by NHTSA on April 8, 2005, which states that the TPMS shall be able to detect 25% pressure drops in one, two, three, or four tires within 20 minutes when driving in 50-100 km/h. With TPI this has been verified in several different vehicles with several different types of tires and on several different types of roads.

TPI also features a special function for detection of very slow pressure drops due to diffusion, small leaks, defective valves etc. in one, two, three, or four tires. With the help of this function TPI can issue accurate and timely warnings for these types of problems, which develop gradually during several weeks or months and significantly increases the risk for tire damages and serious accidents as several studies by NHTSA and other agencies have shown.

Another important safety feature of TPI is that when starting with a flat tire or when a sudden, large pressure loss occurs the system will issue an alarm very quickly, typically within one minute.

2.4 Consistency In Detection Performance And Robustness

TPI can be used on almost any vehicle on the market equipped with an electronic stability control system or anti-locking brake system and will achieve the same level of performance regardless of the vehicle's design (e.g. engine, transmission, chassis, body style, physical dimensions, and weight) and which tires it is equipped with (e.g., summer, winter, or all-season tires, standard radial or run-flat tires). TPI is also robust against temperature and surface variations and against differences in vehicle speed, driving style, load, etc. This has been verified through extensive field tests in different vehicles.

3. ND4 Suite

TPI is included in ND4 Suite, which is a software package of safety enhancement functions for passenger cars, light trucks, and SUVs with an anti-locking brake system.
ND4 Suite is delivered as one software component with a fully documented and easy-to-integrate API (Application Programming Interface). The API is standardized, version independent, and common for all functions, which makes the integration work simple and straightforward. Another advantage is the easy upgrading from one version of ND4 Suite to the next.

Figure 2 below illustrates a typical integration of the ND4 Suite software into the ESC in a vehicle. The ND4 Suite core software is integrated with the other software in the ESC using a specially developed middleware that contains signal interfaces, mapping tables etc. The ND4 Suite software utilizes signals from the wheel speed sensors and from different sensors and systems connected to the CAN bus. The user can interact with the system through menu options in the onboard computer or through a special calibration or reset button. Warning messages or warning symbols are shown on the dashboard or in the onboard computer display.

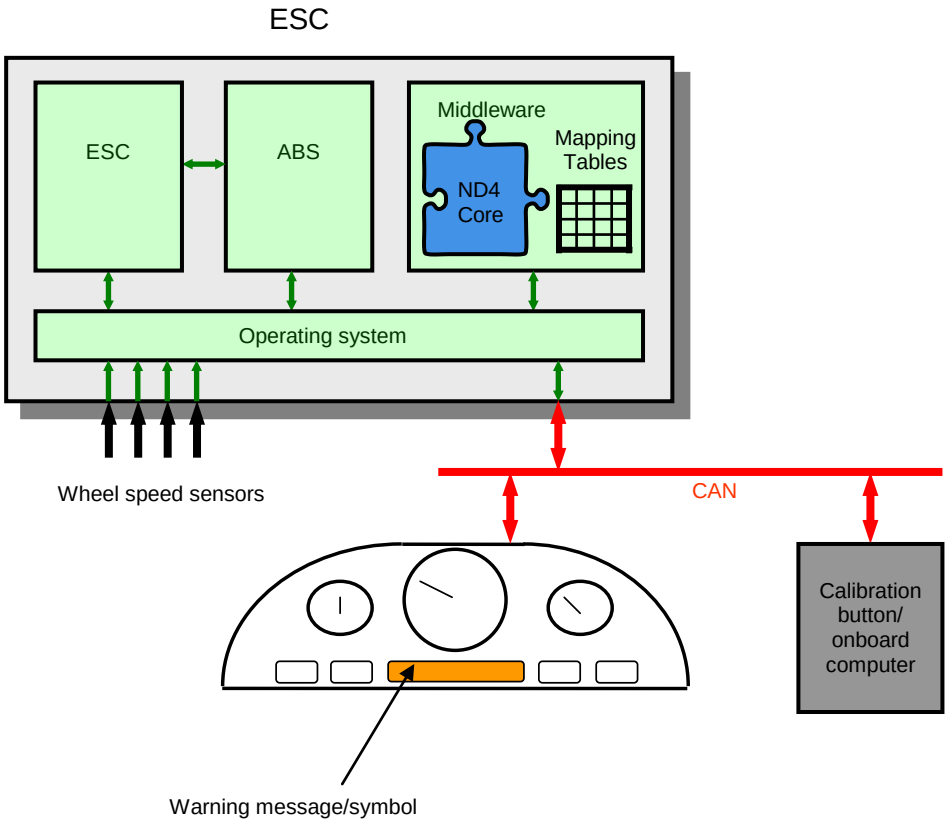

Figure 2 Typical integration of ND4 Suite

4. Contact Information

Address: NIRA Dynamics AB, Teknikringen 6, 58330 Linköping, Sweden
Telephone: +46 (0)13 329800
Facsimile: +46 (0)13 329829
E-mail: info@niradynamics.se
Homepage: www.niradynamics.se