

by **John Day**

Contributing Editor

# Auto Industry Strives for Tire Pressure Monitor Standard

Feds demand detection, driver warning for tires underinflated by 25% or more.

**W**hen it last studied the danger posed by underinflated tires in passenger cars and light trucks, the National Highway Traffic Safety Administration (NHTSA) estimated that as many as 79 deaths and 10,635 injuries could be prevented if all such vehicles were equipped with tire pressure monitoring systems (TPMS). According to NHTSA, 27% of cars and 32% of light trucks have at least one underinflated tire, and 13% of cars and 20% of

trucks have two underinflated tires.

In addition to increasing fuel consumption and shortening the life of a tire, underinflation can lead to premature tire failure from tread separation or blowouts, with the potential for loss of control of a vehicle, according to NHTSA.

The TREAD Act (Transportation Recall Enhancement, Accountability, and Documentation), passed by Congress in November 2000, man-dated a warning system to alert drivers when

one or more tires is significantly underinflated. Some 18 months later, NHTSA issued a rule that allowed automakers to use either direct or indirect tire pressure measurement in their warning systems.

## DIRECT VS. INDIRECT MEASUREMENT

Most direct measurement systems use piezoresistive or capacitive Microelectromechanical system (MEMS) sensors to measure pressure and other parameters in each tire. The sensor signals are sent via a wireless RF transmitter to a central receiver and displayed on a vehicle's dashboard. Indirect sensors use wheel speed sensors on a vehicle's antilock braking system (ABS) to infer pressure based on changes in the radius of a tire relative to other tires.

NHTSA's rule was successfully challenged in court by consumer advocate groups, which charged that indirect measurement is insufficiently accurate. NHTSA revised its rule and submitted it to the Office of Management and Budget (OMB) for review. In mid-September, NHTSA proposed a new safety standard that would require manufacturers to install a four-tire TPMS capable of detecting and warning the driver when a tire is more than 25% underinflated. The standard also calls for a TPMS malfunction indicator that would inform the driver when the system is not working properly.

The pending rule is expected to spur massive worldwide demand for technology able to withstand extreme environmental conditions, but for which relatively little performance data exists.

"Legislation aside, tire pressure monitoring is becoming more of a mainstream product because consumers are much more aware of

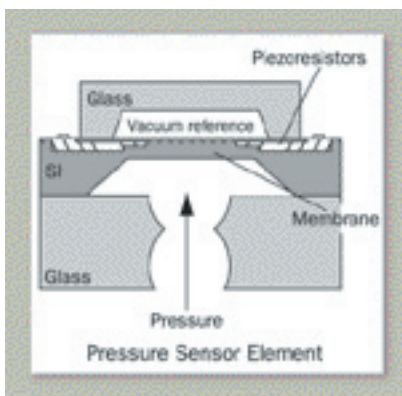


Figure 1. Infineon/SensoNor's MEMS-based pressure sensor.



Figure 2. Siemens VDO's tire guard system housing is designed to withstand 1,000 times the force of gravity and the shock and vibrations of uneven roads.

the importance of proper inflation," said Frank Viquez, director of automotive research at ABI Research in Oyster Bay, N.Y. "It's moving down-market from luxury to middle-segment cars and is becoming a standard feature on a lot more vehicles." He added, "The tire is the most extreme part of a car in terms of harshness, vibration and severe temperature fluctuations."

"We developed our first prototypes in the mid-1980s," recalled John McGowan, senior marketing manager, Sense and Control Products at Infineon Technologies Ltd. in Munich. "We had to specify what conditions semiconductors had to withstand and for tire pressure measurement, then design semiconductors that could withstand them," he said. "Making pressure sensors is not very difficult, but making sensors that can survive within a tire for 10 or 15 years is very challenging."

### CONTENDING WITH HARSH CONDITIONS

MEMS pressure sensor elements, signal conditioning chips and RF transmitters must contend successfully with harsh conditions that include wide temperature variances, intense shock and vibration, moisture, grease, chemicals, dirt, and impact from road hazards.

"Withstanding the temperature, shock, dirt and other conditions was the first engineering challenge we had to meet," said McGowan. Infineon's response, effected in the SP30 sensor module it launched last June, is a triple-stack sandwich consisting of an active substrate between two layers of glass. The 104.5 mm x 104.5 mm device, based on technology developed by SensoNor ASA (Horten, Norway), which Infineon acquired last year, provides pressure, acceleration and temperature-sensing

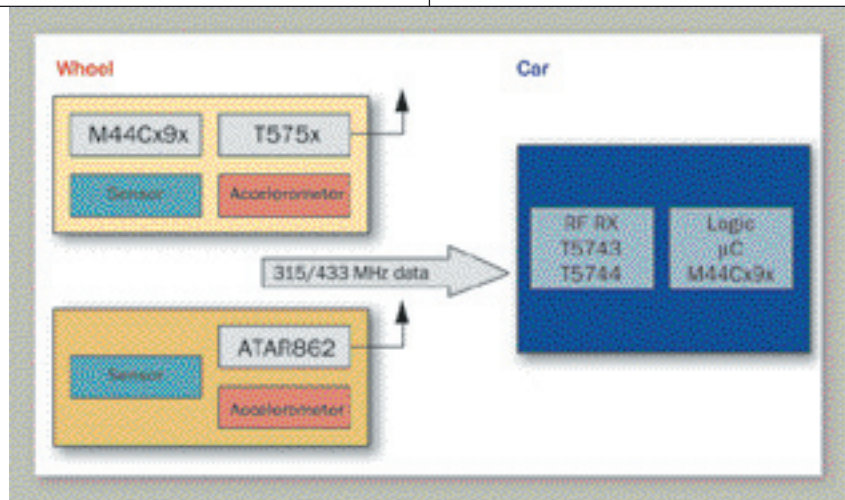


Figure 3. Typical remote tire pressure monitoring system (TPMS) based on UHF unidirectional transmitter/receiver with embedded sensor.

elements, plus a battery voltage monitor and an application-specific integrated circuit (ASIC) for signal conditioning and communication.

McGowan says the SP30 is one of the only tire pressure monitoring devices to integrate an accelerometer. It also includes mask programmability to help automakers deploy the device in multiple systems.

Pressure is measured by a MEMS sensor on a silicon-based vacuum measuring cell. When a diaphragm flexes under variances in air pressure, piezoresistive sensors measure the change, providing accurate data electronically (Figure 1).

Sensor elements in the Infineon/SensoNor device are made by bulk micromachining of silicon (BMM) and use advanced photolithographic processes, ion implantation, wet and dry etching, and triple-stack anodic bonding, with the latter forming a sealed cavity vacuum reference chamber. The device is subsequently embedded in a vibration-absorbing compound and a plastic housing attached to the rim of the wheel.

Leveraging its experience in RFID passive keyless entry technology, Royal Philips Electronics focuses on the signal conditioning aspect of tire pressure measurement,

according to Hartmut Frerichs, product manager for Tire Pressure Monitoring at Philips Semiconductors, Hamburg, Germany. Solution providers typically combine tire pressure and keyless entry into one receiver unit, and Philips' P2SC signal conditioning chip provides the link between the tire module and the driver interface.

The chip offers low-frequency wakeup and high-frequency return, enabling the system to poll each tire for its current pressure and position. Each tire is awakened whenever the ignition is switched on to give the driver status information on the tires before he or she starts to drive. An adaptive wakeup pattern provides regular status updates while driving. If pressure drops suddenly, the tire relays information automatically without having to be polled or awakened.

Frerichs explains that the low-frequency wakeup feature identifies the correct wheel transmitter automatically, even after a tire position has changed during maintenance, thus eliminating the reprogramming that would otherwise be needed. The Philips chip is designed to be mounted directly onto a tire rim, and can withstand shock resis-

tance up to 2,000 G and temperatures of up to 175°C.

### TECHNOLOGY EVOLVING RAPIDLY

Tire pressure technology is evolving rapidly. "We're working toward a single ASIC that will incorporate all power management, all intelligence and the RF portion of the sensor. These have been separate pieces," said John Maxgay, lead design engineer for tire pressure monitoring sensors at the General Motors Tech Center in Warren, MI. "One tier two suppliers will be responsible for all of that. We're moving toward a common architecture, with a common sensor, receiver and RF protocol."

"Sensors all talk the same way," Maxgay continued. "There is an ID string within the RF transmission, and when a vehicle is built, the system has to know which IDs to pay attention to and to ignore all of the others. A training step is needed whenever sensors are replaced, and when tires are rotated, ID information has to be updated."

The design of the RF transmission function has a major influence on overall system reliability, according to Ward Randall, business development manager for the Body and Chassis Electronics Group at Siemens VDO in Auburn Hills, MI, developers of the Tire Guard TPMS.

Sensor measurement values are typically transmitted at 315 MHz in the United States or 434 MHz in Europe. Optimizing sensor output power requires that signal quality be balanced against energy consumption and battery life. To minimize interference, system designers can use higher baud rates to shorten transmissions, transmit at irregular intervals and transmit multiple times. To withstand the harsh environment of the vehicle tire, Siemens VDO has its sensor embedded in a vibration-absorbing compound in a plastic

housing. This housing, attached to the rim of the wheel with the valve stem nut, is designed to handle 1,000 times the force of gravity and the shock and vibrations of uneven roads (Figure 2).

"There are a large number of (potential) solutions without a large body of historical data," noted GM's Maxgay. "There's a lot of discussion around the way you design the RF protocol. Should it be an AM or an FM sensor? What's the baud rate? You can send more messages in a short period of time with a higher baud rate, but there's also a greater chance that the bit error rate will go up. We're keeping an eye on the technology, which is changing so fast. A 9.6 kilobaud rate wasn't doable a couple of years ago, but is doable now. GM currently uses a 4.2 kilobaud AM sensor in Corvettes and Cadillacs.

"We have an FM sensor, but have some concerns about integrating it with our keyless entry module. Keyfobs tend to talk on AM. We can switch the receiver to FM mode and then talk to tire pressure sensors, but we're anticipating compromises in our antenna and receiver technologies if we continue to have our receiver combined with keyless entry. We're continuing with AM technology, but a lot of folks are talking about going to FM. We're migrating toward a common solution."

Maxgay said GM is continuing to work with tire and wheel makers on integrating pressure sensor assemblies with valve stems. "We want the sensor packets to fit rim profiles without overly compromising rim designs," he said. We've developed a package envelope that we require sensor suppliers to fit into, and we require that wheel designs accommodate those sensors. The smaller we can make the package, the better. Sensor manufacturers are sensitive to those concerns. We're also working with the after market and service folks. Typically, drivers don't go back to the

dealer to get their tires replaced, so we're working as hard as we can to educate tire shops about sensors and how to take care of them."

### POWER MANAGEMENT

Because power management is so important to long battery life, and vehicles are parked most of the time, Maxgay says a pressure sensor module must be able to tell if a vehicle is moving or not. "At one time we used a ball and spring arrangement, but we've worked with our supplier to come up with a solid-state solution that uses an accelerometer for sensing motion. It's patent-protected, though most folks today have some type of solid-state solution for detecting motion.

"We used to use a bimetal switch—two pieces of which would close together when a magnet was held next to it," he says. "Sometimes, the switch would close on its own so we moved to a solid-state solution. We use a low-frequency signal to perform the function that the mechanical switch used to perform."

Significant attention is being paid to conserving power. Atmel Corp., among other firms, markets devices that wake up sensors during defined duty cycles. Atmel's design incorporates a 125 kHz wakeup channel, as well as microprocessors and RF circuitry. In April, the company introduced two UHF ASK/FSK transmitter ICs for TPMS (Figure 3).

Typical of the batteries that drive TPMS are Lithium Manganese Dioxide (Li/MnO<sub>2</sub>) coin cells from Maxell Corporation of America, CR2450-HR and CR2450HR-EX. Mounted on a vehicle's wheel rims, the cells feature gasket material, a crimping structure and content all designed for use in high-temperature environments (Figure 4). The CR2450-HR, for standard vehicles, operates from -40 to 120°C, has a standard capacity of 550 mAh and

weighs 6.8 grams. The HR-EX version, for high-performance vehicles, operates between -40 to 150°C, has a capacity of 525 mAh, and weighs 6.7 grams. Both cells measure 24.5 mm in diameter x 5 mm high.

Several suppliers are working on battery-less TPMS. SmarTire Systems Inc. in Richmond, BC Canada, for example, is testing a battery-less tire pressure and temperature monitoring system that also tracks tire revolutions. A passive sensor inside each tire is energized by an antenna located within each wheel arch. SmarTire president Robert Rudman said elimination of the battery in a sensor reduces weight, size and cost, adds to sensor life and reliability, and avoids battery disposal issues. Furthermore, the battery-less system allows tires to be rotated or changed without reprogramming.

Alps Electric Co. Ltd. in Tokyo, has developed a battery-less TPMS based on technology licensed from IQ-mobil GmbH in Wolfratshausen, Germany. Based on proprietary wireless high-frequency wave technology, Alps' device includes a transceiver and a transponder that uses the energy of the transceiver signal to transmit data from pressure and temperature sensors. Echoing the weight loss benefit, Alps contends that a battery's weight can cause distortion of a tire's shape at high speeds, resulting in a loss of pressure and concomitant safety problems.

Texas Instruments' sensors & controls business unit in Attleboro, MA, takes a different tack with a battery-less sensor that combines truck tire identification with real-time pressure and temperature monitoring. Its InTire Sensor is part of Michelin's eTire asset management system. Designed for mounting on a tire's inner lining, the sensor uses a capacitive MEMS device to sense tire pressure and temperature. Hand-held or drive-by readers communi-



Figure 4. Maxell's high temperature resistant lithium manganese dioxide coin cells.

cate wirelessly with the sensor to read sensor and ID information.

GM's Maxgay is skeptical. "A battery-less TPMS is a consideration, more so in Europe for reasons of recyclability," he said. "In the U.S., there are some benefits, but we're struggling to see the business case.

"Vehicles have four sensors talking to a central receiver. We're getting good quality sensors at good prices. With a battery-less device, we need some way to get energy into the sensor; typically some sort of black box mounted on the wheel well. We pull a battery, but have to mount a black box in each corner. We've integrated the tire pressure receiver with the keyless entry receiver, but with a battery-less design we'd need a stand-alone controller. We want to communize our architecture, and the receiver in place today doesn't accommodate that distributed tire pressure control," he asserted.

"When we add all the pieces back in there's a significant added cost over what we're paying today. The driver gets the same functionality.

We get the same (Federal) compliance. With a clean sheet of paper, it might be worthwhile, but since we already have a receiver integrated with a keyless entry receiver, the benefits aren't quite there."

On the other hand, Maxgay admitted, "There could be benefits we haven't thought about. For example, (battery-less TPMS) could help accommodate the differences in wheels and tires. There may be situations we can't overcome with a central receiver, given limits on how loudly and how often we can talk. We're just not ready to jump all the way." ■

#### ABOUT THE AUTHOR:

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