

## 7a. TPM Module Description of Operation

This TPMS module is a direct measurement type system that is designed to monitor the actual pressure within an automotive tire. In general, the TPMS module provides the FMVSS required warning of a low tire pressure condition to the vehicle driver. The TPMS system comprises three modules: the Receiver (RX), optional Low Frequency Initiators (LFI), and the Wheel Electronics (WE) sensor units. The WE sensors are located within each tire, and provide an accurate measure of the pressure and temperature within the tire. The WE sensors periodically transmit high frequency RF signals with this pressure and temperature data to the RX module which determines if there is a low pressure condition in a tire. If necessary, the RX will warn the vehicle operator by lighting a warning lamp. On vehicles equipped with Low Line (L/L) systems, a single lamp (TREAD) warns of a pressure fault in any of the monitored tires. The vehicle operator will need to determine manually which tire or tires are low. Vehicles with High Line (H/L) systems have a Low Frequency Initiator module at each wheel well. The LFI modules are controlled by the receiver to enable the system to determine the position of each WE sensor unit, and thus report to the vehicle operator the location of a tire with a pressure fault. The High Line system has the TREAD lamp as well as four lamps to indicate tire position on the vehicle. Both systems also have a warning lamp (TPMS) that indicates when a system fault has occurred and the system is unable to perform its functions. The receiver module also incorporates diagnostic capabilities via a K-line serial communications diagnostic link.

The LOW LINE TPMS Receiver module's MCU and RF receiver circuits are active while the vehicle's ignition circuit is energized. It continuously monitors for RF broadcasts from nearby WE units. The Receiver module has nonvolatile memory in which the ID codes of the WE sensor units fitted to that particular vehicle are stored. When the Receiver module receives an information broadcast, it checks to see if the ID code contained within that broadcast matches one of the ID codes stored within its nonvolatile memory. If this is the case, the Receiver module applies the information contained within that broadcast to the TPMS Warning Algorithm. This algorithm evaluates the pressure and temperature of each tire for changes over time, and is responsible for making the decision to alert the driver to a potentially dangerous tire inflation condition via a visible 'TREAD' indicator. In addition to processing data from the WE sensor units, the Receiver module is also capable of self-diagnosis of its circuitry and operating condition. If a serious fault is detected, the Receiver module can alert the vehicle operator to this condition by means of a second visible 'TPMS SYSTEM WARNING' indicator.

A HIGH LINE TPMS Receiver module performs the same functions as the LOW LINE RX module, but in addition is equipped to control four Low Frequency Initiator (LFI) modules fitted to the vehicle near each of the four tire locations. When the ignition circuit is first energized, the Receiver module will activate each of the LFI modules one at a time. The coded electromagnetic field from the LFI module causes a nearby WE sensor to temporarily suspend normal processing and broadcast an RF message. The message content is the same as those normally generated by the WE sensor, with the exception that the operating state information within the broadcast reflects that the WE sensor has detected the coded electromagnetic field from a nearby LFI module. Upon reception of the broadcast from the WE sensor, the Receiver module will be able to associate the unique WE ID code with the wheel's position on the vehicle. This "auto-location" process takes place each time the vehicle's ignition circuit is energized, so that changes in wheel position will be noted. The TPMS Warning Algorithm continues to evaluate the pressure and temperature of each tire, and is responsible for making the decision to alert the driver to a potentially dangerous tire inflation condition via a visible 'TREAD' indicator. It will also indicate the appropriate tire position via the 'Front Right (FR)', 'Front Left (FL)', 'Rear Right (RR)', and 'Rear Left (RL)' indicators.

## 7b. RF Receiver Description of Operation

The TPMS module RF receiver consists of an integrated low noise amplifier (Infineon BGA420) coupled to an integrated low power superheterodyne receiver (Infineon TDA5211). A 315MHz band-pass (SAW) filtering is applied between the LNA and superheterodyne receiver. The low noise amplifier and superheterodyne receiver are tuned to receive frequency-shift-keyed (FSK) data in the 315MHz frequency range. The receiver IC contains a low noise amplifier, double balanced mixer, fully integrated VCO, PLL synthesizer, crystal oscillator, limiter with RSSI generation, PLL FSK demodulator, data filter, data comparator, and peak detector. The signal at the receiver IC input is amplified by an internal LNA which has a voltage gain of 15 to 20 dB. A double balanced mixer then down-converts the 315MHz signal to a 10.7MHz intermediate frequency (IF) by high side injection at the mixer with a division ratio of 32. A 10.178 MHz crystal oscillator frequency is used for the IF generation. FSK demodulation is achieved by an internal PLL circuit. The demodulated data is then filtered and fed into a data slicer. The data slicer is a fast comparator with a bandwidth of 100 kHz. It compares the analog input data with a self adjusting reference level generated by an RC term. The output of the data slicer, which is the receiver data out, is a digital signal (CMOS-like levels).