



# The SPEC of Tire Pressure Monitoring System OEM Version

## 1 Introduction

### 1.1 Why Monitor Your Tire Pressure?

Most people ignore their tires. Tires are undoubtedly the most critical safety component on a vehicle. Where the rubber meets the road affects traction, handling, steering, stability and braking. Because of this, a sudden tire failure can have serious consequences, especially if it occurs at highway speeds.



Yet people neglect their tires and assume that all is well unless they appear totally flat, at which point it is too late!

And now some statistics for you - did you know?

- Nearly 250,000 accidents per year occur in the United States alone due to low tire pressure
- 75% of roadside flats are preceded by a slow leak or under inflation condition
- According to a recent survey, it was found that if Americans cut their fuel consumption by 10%, they could save a collective of \$2 billion a year. You could be saving \$674 a year on fuel for your SUV by keeping your tires properly inflated. (Figure 1)
- Up to 40 per cent of European motorists are riding around on underinflated tires, which affects directional stability, fuel economy, and tire wear rates
- Surveys conducted in the UK found that 80% of motorists fail to regularly check their tires
- A tire can lose up to half of its air pressure without appearing to be underinflated.

The best tread designs and the most expensive tires are nothing without the air that carries them along. Checking tire air pressures is such a small investment in time compared to the costs related to replacing tires put out of service because of improper inflation.

NHTSA estimates that the installation of tire pressure monitoring systems, which would

warn drivers of an underinflated tire, could prevent as many as 79 deaths and 10,365 injuries each year in the US alone.

**Figure 1**



The difference between a correctly inflated tire (top) and one with only 70% pressure (bottom) is difficult for a typical driver to see.

## **1.2 Wireless sensors eye tire pressure**

*Tire-pressure monitoring is one of the biggest safety improvements that electronics technology can give drivers. Direct-pressure-measurement systems have now set the stage to displace alternative approaches.*

By David Marsh, Contributing Technical Editor -- EDN, 9/2/2004

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## 2 TPM System SPEC Overview

### 2.1 The Overview of TPM System

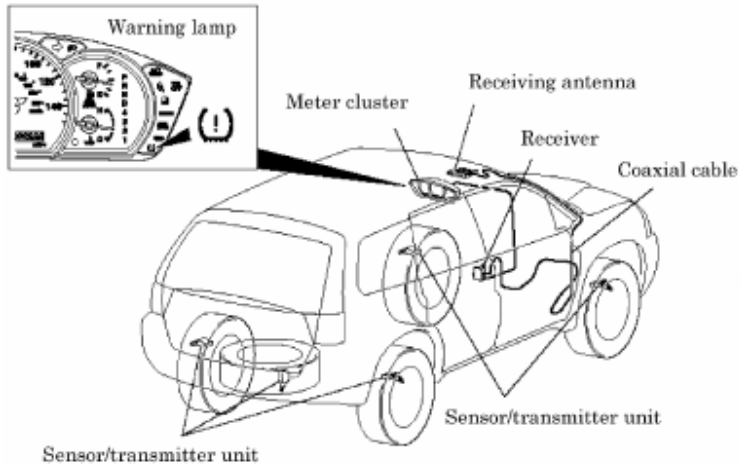


Fig.2

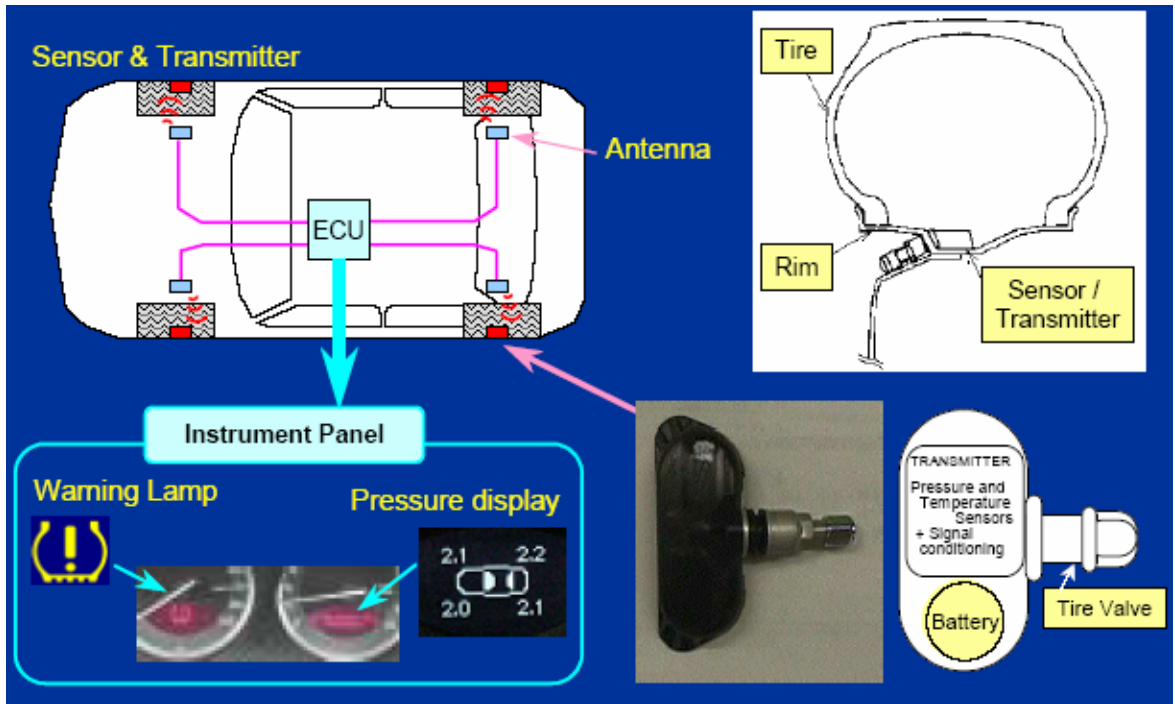
As shown in **Fig. 2**, the Orange's tire-pressure monitoring system consists mainly of sensor/transmitter units, a receiving antenna, a receiver, and a warning lamp.

Tire-pressure values measured directly by the sensor/transmitter units are transmitted as radio signals to the receiver via the receiving antenna. The receiver determines whether the tire-pressure values are acceptable.

If it identifies an abnormality, it causes the warning lamp (this is located in the meter cluster) to illuminate to warn the driver of the need for a tire-pressure check.

Since tire-pressure values are transmitted as radio signals, there is a risk that the receiver will receive signals from the sensor/transmitter units of other vehicles equipped with the same type of system. To enable the receiver to identify and use signals from its own sensor/transmitter units and ignore those from other vehicles' sensor/transmitter units, each sensor/transmitter unit has a unique identification code, which it transmits together with tire-pressure data. The receiver is programmed to recognize the identification codes of its own sensor/transmitter units, so it uses only the relevant tire-pressure data to determine the necessity of activating the warning lamp.

Further, the receiver is programmed to activate the warning lamp not only in the event that it receives abnormal tire-pressure signals but also in the event of an abnormality in the system's operation (for example, failure to receive signals from the sensor/transmitter units). The receiver causes the warning lamp to illuminate continuously for a tire-pressure warning and to flash for a system-malfunction warning, so the user can differentiate between the two types of warning.



## 2.2 The Main structure of TPM System

### 2.2.1 The Receiver

- The receiver can be supported various interfaces into the automotive onboard computer communication bus/ lin, bus/iic

The receiver is programmed at the factory to recognize which sensor is at each wheel location. If tires are rotated or a sensor is replaced, the receiver must be reprogrammed, following replace procedures, the receiver will automatic recognize the location of each tire sensor ID.

If the TPMS Warning Light (see Figure 3) flashes or stays ON, please use the “TPMS Diagnostic Chart” to resolve the incident.

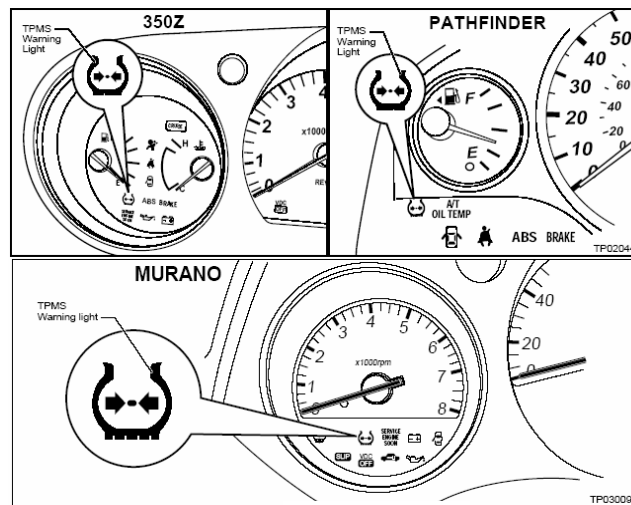

















Figure 3



TPMS Diagnostic Chart

Diagnosis Item	Symptom (with key ON)	TPMS Warning Light	Cause	Action
Warning Light (instrument panel)	Warning light immediately comes ON and turns OFF after 1 second	  ON 1 sec > stays OFF	All wheel transmitters are "activated" (working)	None (system OK)
	Warning light blinks ON for 2 seconds, then turns OFF for 0.2 seconds - repeats	 Blinks:  ON 2 sec > OFF 0.2 sec	All wheel transmitters are NOT activated	Activate all wheel transmitters. See "Wheel Transmitter ("Wake Up") Activation Procedure" on page 4.
	Warning light blinks 1 time	 Blinks 1 time ON 0.3 sec > OFF 1.3 sec	LF wheel transmitter is NOT activated	Activate LF wheel transmitter. See "Wheel Transmitter ("Wake Up") Activation Procedure" on page 4.
	Warning light blinks 2 times	  Blinks 2 times ON 0.3 sec > OFF 0.3 sec	RF wheel transmitter is NOT activated	Activate RF wheel transmitter. See "Wheel Transmitter ("Wake Up") Activation Procedure" on page 4.
	Warning light blinks 3 times	   Blinks 3 times ON 0.3 sec > OFF 0.3 sec	RR wheel transmitter is NOT activated	Activate RR wheel transmitter. See "Wheel Transmitter ("Wake Up") Activation Procedure" on page 4.
	Warning light blinks 4 times	    Blinks 4 times ON 0.3 sec > OFF 0.3 sec	LR wheel transmitter is NOT activated	Activate LR wheel transmitter. See "Wheel Transmitter ("Wake Up") Activation Procedure" on page 4.
	Warning light comes ON and does NOT turn OFF	 Comes ON and stays ON	<ul style="list-style-type: none"> <li>Long Term Storage Fuse pulled out</li> <li>TPMS ECU connector pulled out</li> <li>Low tire pressure or TPMS system failure</li> </ul>	<ul style="list-style-type: none"> <li>Check storage fuse, see Figure 2, page 4. Install or replace (if needed).</li> <li>Check TPMS ECU connector. Re-connect if needed.</li> <li>Perform CONSULT Self Diagnosis: <ul style="list-style-type: none"> <li>- Press "Start"</li> <li>- Press "Tire Pressure Monitor System MENU select"</li> <li>- Press "Self Diagnosis MENU select"</li> <li>- Press "Start"</li> </ul> </li> <li>See Service Manual</li> <li>Perform ID Registration if needed</li> </ul>
Parking Lights	Parking lights do NOT flash 2 times after transmitter activation.		<ol style="list-style-type: none"> <li>1. Tool J-45295 battery low.</li> <li>2. Ignition OFF during activation.</li> <li>3. Tool J-45295 not positioned correctly.</li> <li>4. Transmitters already activated</li> </ol>	<ol style="list-style-type: none"> <li>1. Install new battery.</li> <li>2. Make sure ignition is ON during activation.</li> <li>3. <u>Position tool correctly</u> during activation (see Figure 4).</li> <li>4. None.</li> </ol>

**NOTE:** If more than one wheel transmitter is NOT activated, the blinking patterns for those wheels will combine. (Example: one blink/OFF/three blinks = LF and RR transmitters are not activated.)



**Specific function :**

1) In the case of a low tire pressure condition, the TPMS warning light will come on. To turn the light OFF, do the following:

- **Re-set** the tire pressure to the correct setting.
- **Drive** the vehicle over 25 MPH for several minutes.

2) The wheel transmitters send updated pressure information to the control unit as follows:

Vehicle parked with ignition switch ON

- Updated pressure information sent every **hour**.

Vehicle driven over 25 MPH

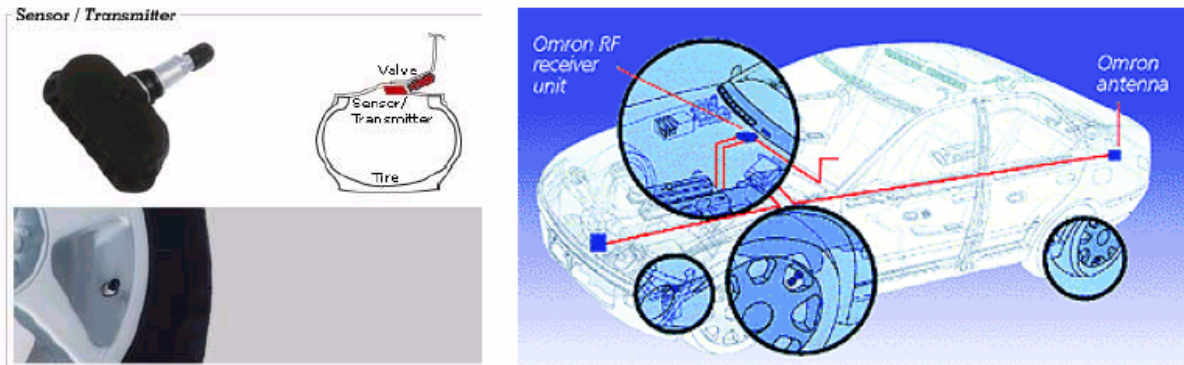
- Updated pressure information sent every **minute**.

Vehicle parked with ignition switch OFF

- No pressure information sent to control unit. CONSULT-II will indicate "0"\* pressure.
- To update pressure information quicker, drive the vehicle over 25 MPH for a few minutes.

### 2.2.2 The Transmitter

The most important of components of TPM System, which are the transmitters. This device transmit the accurately data to receiver, and inform the driver these tires' pressure and temperature. Thus, the sensor of pressure and temperature, antenna's transmitting distance, frequency, and the battery's life, and the weight of transmitter become the key function for these transmitting.



Orange has two solutions for OEM markets, we separate **standard function** and **advanced function (option)**.

The TPMS contains a component for electric power supply. The main components of an active battery operated tire pressure monitoring system are battery, processor, memory, sensors, radio component and antenna. These components are integrated on single chips (ASIC) to save weight and space and to reduce power consumption. The sensors typically measure pressure and temperature. Orange also use a simple acceleration sensor or a switch that helps determine whether the tire is rotating or not.

This is an original equipment system, in other words, installed during the car manufacturing, the receiver is typically integrated into the car and connected with an external display and keyboard, e.g. the control panel of the car. Sometimes the receiver can be more or less integrated in the remote keyless entry system of the car. In some OE-products the receiver uses several antennas, one near each wheel. In such a case, the positions of the tire sensors under the vehicle can be automatically detected.

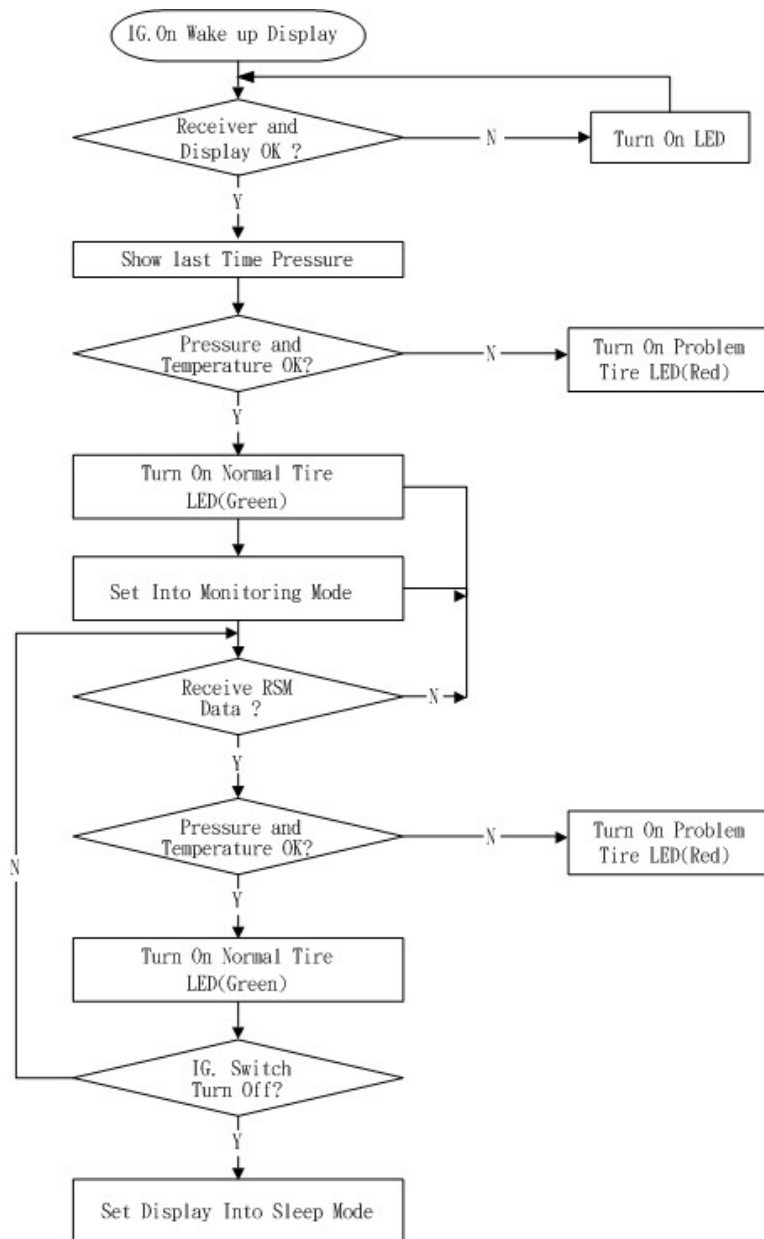


## **2.3 The Control Flow chart**

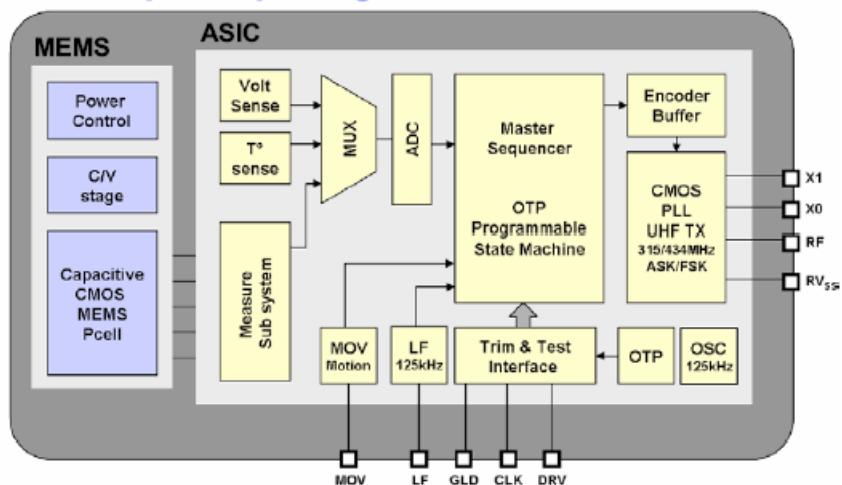
### **2.3.1 Standard solution**

In the Stand Solution, the transmitter embedding an accelerated sensor, when vehicles driven over 25 MPH, the transmitter will auto wake up and act the detection job for the temperature and pressure of a tire.

Meanwhile, the when the vehicle parking over 1 hour, the transmitter will auto sleep to save power of battery. During the sleeping period, the transmitter still will detect and transmitter the temperature and pressure to receiver every hour per time. Thus, when driver switch on the ignition, the receiver will be shown the last time (less than 1 hour before) each tire's data. Except this trigger, when a vehicle driving, any emergency for each tire of temperature and pressure problem happened, the transmitter will immediately transmit the signal to receiver. And the receiver will shown the warn light and sound to warn the driver immediately.



Two Chip, one package



**Advanced solution (Option)**

In Advanced solution (Option) of Orange design. It will add a trigger in each transmitter of tire. Meanwhile, the transmitter will not be wake up by Vehicle driven over 25 MPH, but when the driver switch on the ignition, the receiver will send a signal to each tire and wake up the transmitter to activity. Then the transmitter will immediately transmit the tire temperature and pressure to receiver.

This function like all the car system, when a driver switch on the ignition, the ECU will check all the engine parts and shown what result before vehicle move.

Below figure 4 can easy compare the different for the Basic solution and Advanced solution (option)

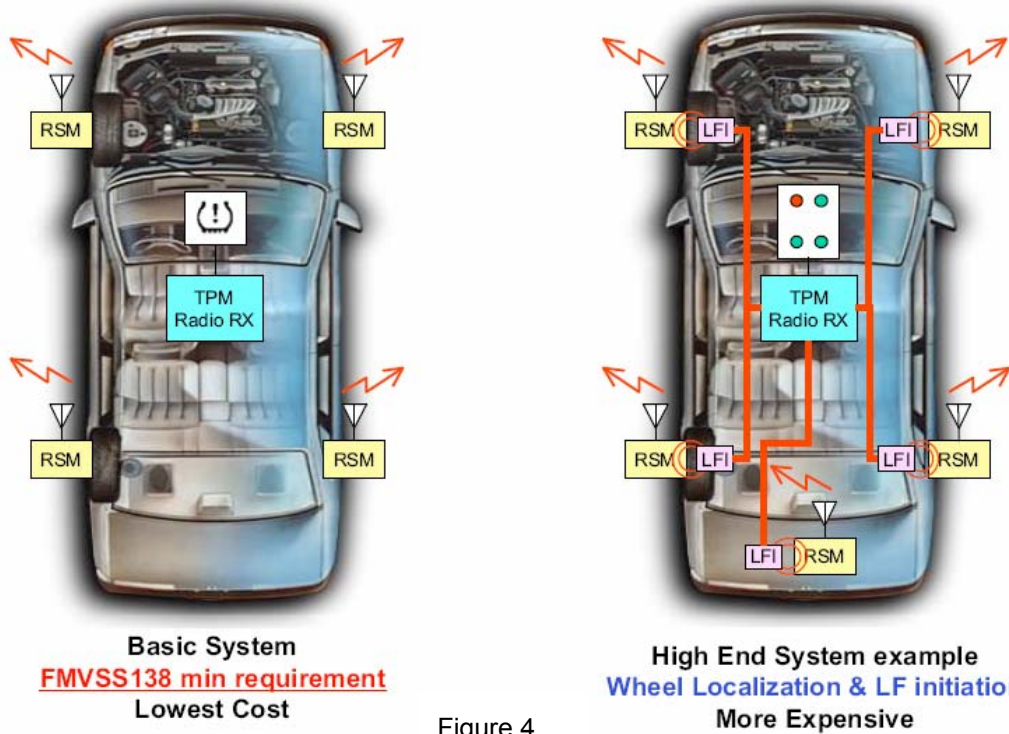
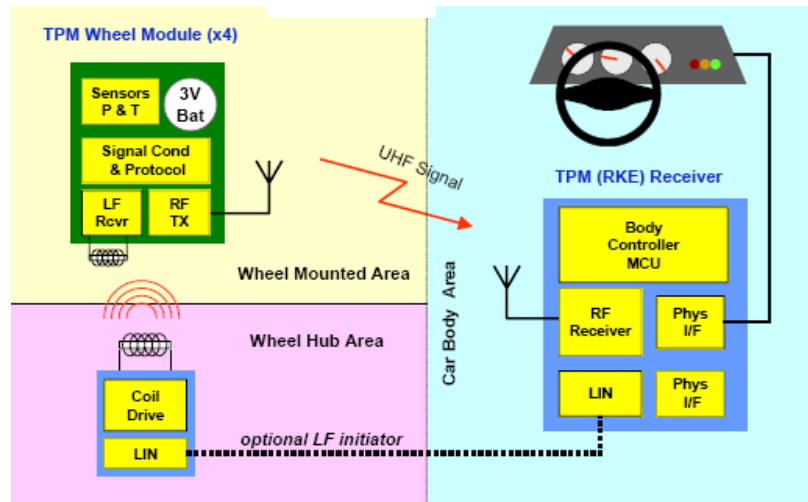
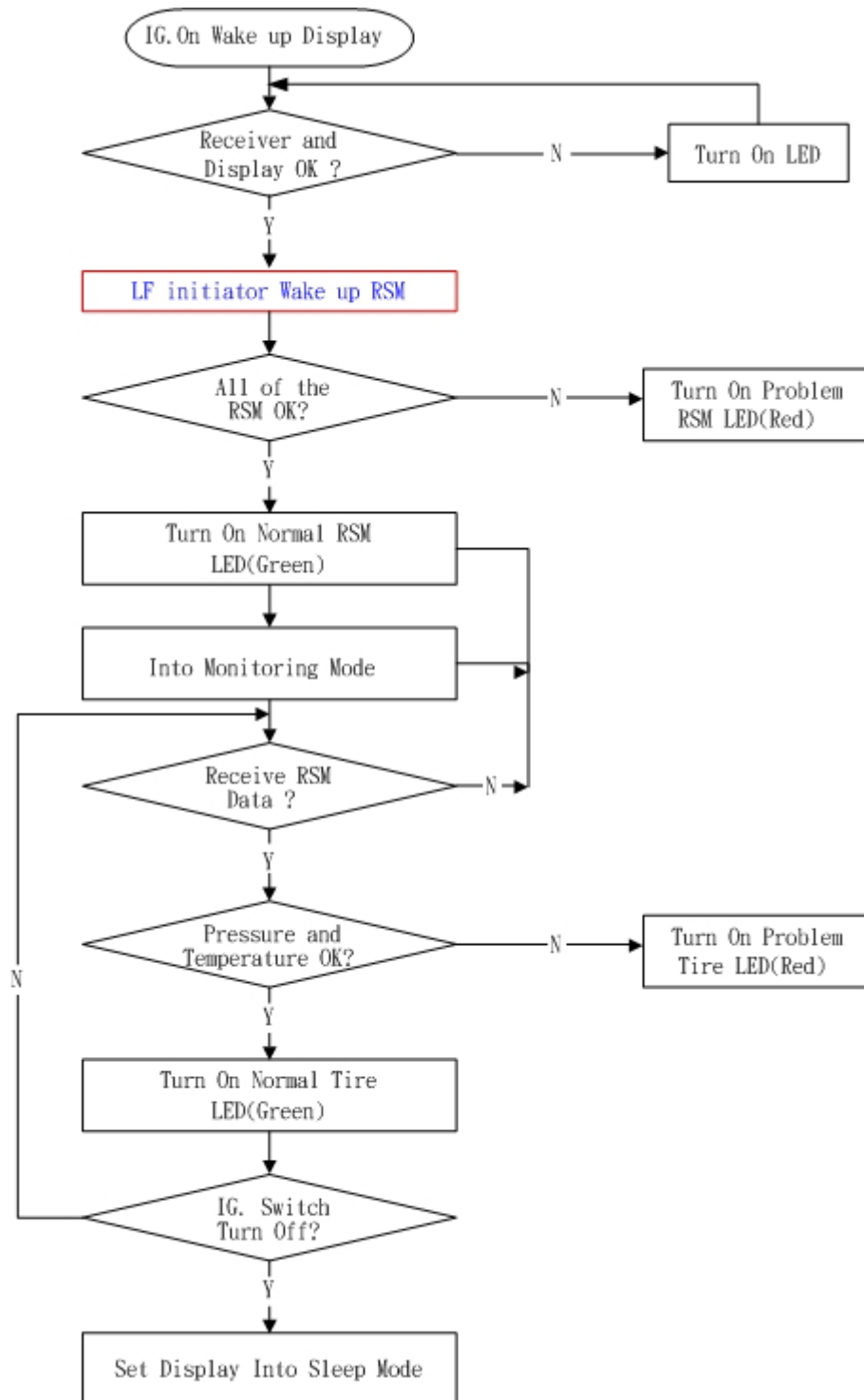
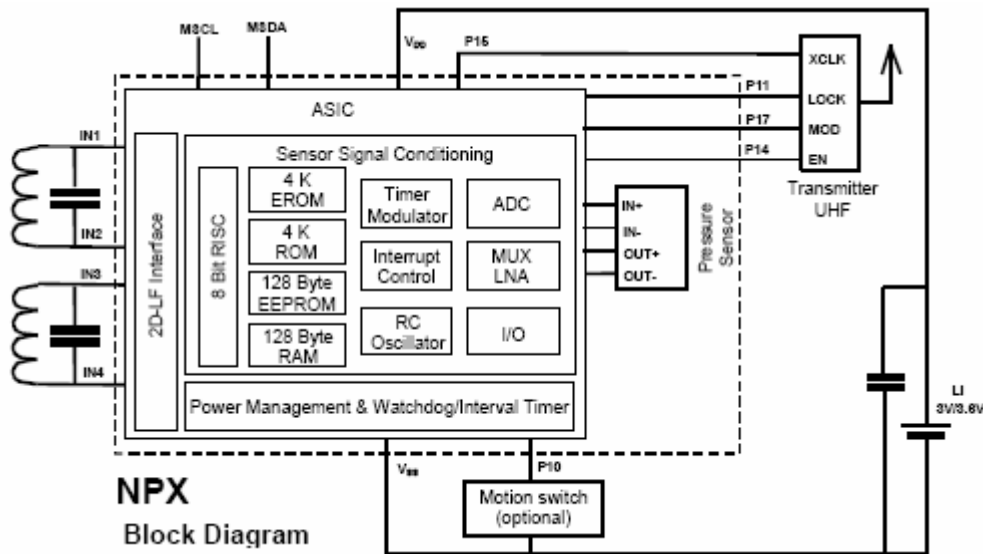


Figure 4



The flows chat for the Advanced Solution (option)





## Specifications

PARAMETER	SPECIFICATION				AMBIENT CONDITIONS		NOTES
	Min	Typ	Max	Unit	Temp [°C]	VDD [V]	
<b>Pressure Measurement</b>	The presented performance reflects the use of 12bit sampling of pressure signal.						
Pressure Ranges	100-450	100-700	0-1400	kPa	-40 to 125		
450 kPa Resolution		1.37		kPa/LSB	-40 to 125		(450kPa-100kPa)/255
700 kPa Resolution		2.35		kPa/LSB	-40 to 125		(700kPa-100kPa)/255
1400 kPa Resolution		5.49		kPa/LSB	-40 to 125		(1400kPa-0kPa)/255
<b>ALL PRESSURE RANGES</b>	The presented performance reflects the use of 12bit sampling of pressure signal.						
Measurement Accuracy	-6		6	LSB	0 to 50	2.1 to 3.6	6σ capability
Over Pressure		10X					
450-1400kPa Measurement Charge Consumption		11		Micro-coulombs	25	3.5	
<b>Temperature Measurement</b>	The presented performance reflects the use of 10 bit sampling of temperature signal.						
Temperature Range	-40		125	°C			
Resolution		1.0		°C/LSB			(205°C-(-50°C))/255
Measurement Accuracy	-6		6	°C	-20 to 70	2.1 to 3.6	6σ capability
Measurement Charge Consumption		5		Micro-coulombs	25	3.5	
<b>Battery Voltage Measurement</b>	The presented performance reflects the use of 12 bit sampling of battery voltage signal.						
Resolution		10.80		mV/LSB			(4.0V-1.246V)/255
Measurement Accuracy	-60		60	mV	-40 to 125	2.1 to 3.6	6σ capability
Measurement Charge Consumption		4		Micro-coulombs	25	3.5	
<b>TMAX</b>	ϕ <sub>SHTD</sub> represents the temperature at which the Thermal Shut-down function can be enabled and ϕ <sub>REL</sub> represents the temperature at which the Master Reset state is released.						
ϕ <sub>SHTD</sub>			115	°C	-40 to 175	2.1 - 3.6	Thermal shutdown enabled
ϕ <sub>REL</sub>	100			°C	-40 to 175	2.1 - 3.6	Master Reset Release
<b>VMIN</b>	The voltage at which the Vmin-circuit will return a low battery voltage status is specified in:						
Vmin	2.0	2.1	2.2	V	-40 to 125	1.5 - 3.6	



## **2.4 The Components of Orange for TPM System**

### **2.4.1 Sensor**

#### **MEMS (CMOS + MEMS) MEMS (CMOS + MEMS)**

- PIDR73%, Based on Licensed Technology from Fraunhofer for Capacitive Pressure Sensors Integrated with CMOS
- Low Current Capacitive Technology
- 15% dC/Co
- Temperature Compensation, Signal Conditioning

#### **ASIC ( ASIC (SmartMOS SmartMOS™)**

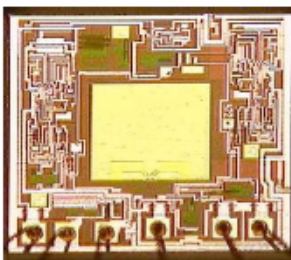
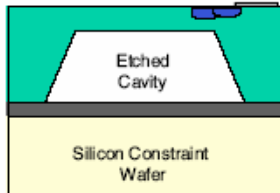
- SmartMOS Control ASIC
- State machine for low cost & low power
- Temperature Sensor
- On-chip over temperature shutdown
- Pressure, Temperature & Voltage Signal Paths
- On-chip 315/434 Mhz PLL based RF output
- 9600/19200 bps FSK or 4800 bps ASK modulation
- LF receiver for diagnostics & remote initiation
- Motion input to modify protocol
- Multiple protocols & options selected by on volatile memory (NVM)
- Power management specific to TPM
- Device ID & RF preamble programmed in NVM

#### **Package Package**

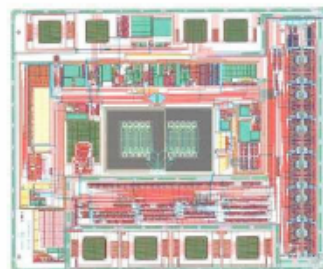
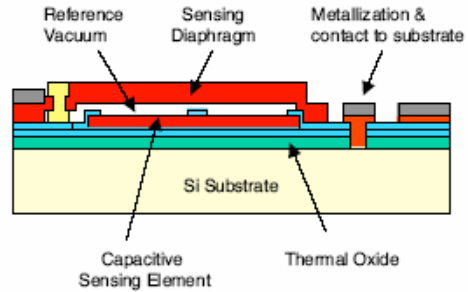
- 16-lead Pressure-SOIC
- Teflon Filter Media Compensation

## MEMS Pressure Sensors

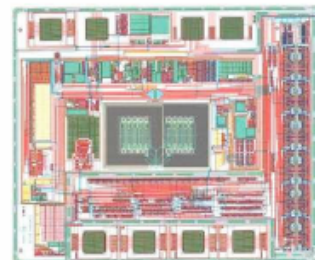
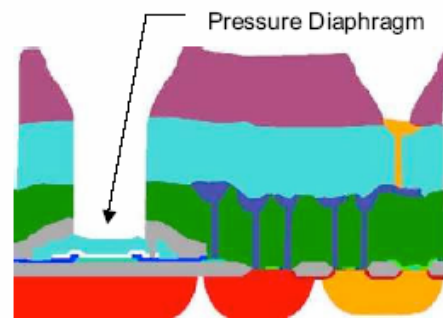
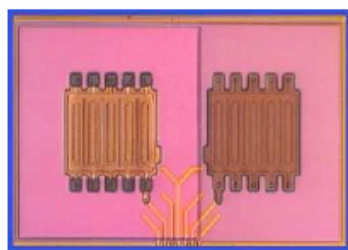
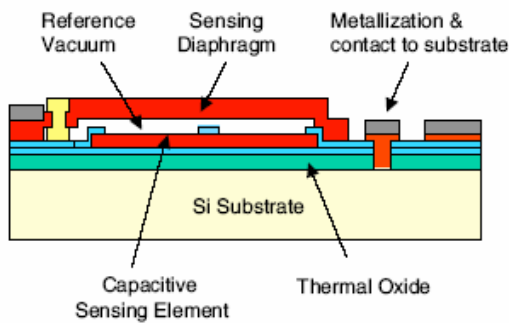
### Bulk Micro machining

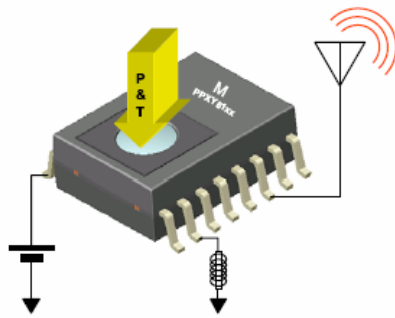


### Surface Micro machining



## Surface Micromachining and CMOS Integration





## 2.4.2 Battery

### Technical requirements of TPMS systems for Battery

Depending on the application, the electrical and mechanical requirements differ widely from each other.

- A TPMS battery, for instance, should work for up to **10 years** inside the wheel.

The load profile typically consists of a small (or no) background current and pulse currents in the vicinity up to 10 mA and 5 – 10 ms duration. Shock, vibration and centrifugal forces are very demanding.

- The temperature range limits the range of applicable lithium battery systems.

Whereas electrical and mechanical load profiles can vary depending on the application, the temperature profile is very demanding, independent of the application.

Standard temperature range for automotive applications is - 40°C to 125°C.

It is exceeded for TPMS applications to excursions **up to 150°**

### Orange Technical Data for the Battery

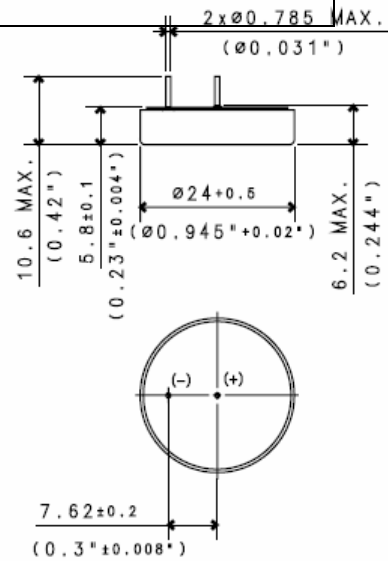
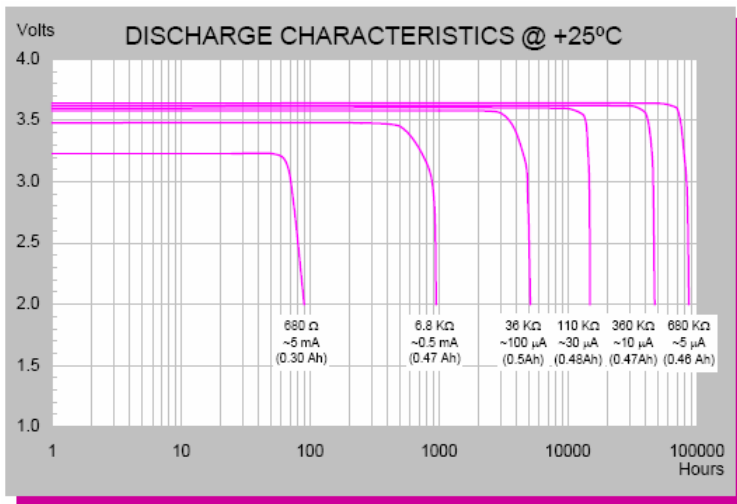
(Typical values @+25°C for batteries stored for one year or less)

In order to meet the requirement of OE testing, Orange choose the high standard of Battery for TPMS, and this special battery is only developed for TPMS specific only. Currently, this battery has been proved by BMW, and using in all the TPMS of BMW cars.

The SPEC and testing data of this Battery as below:

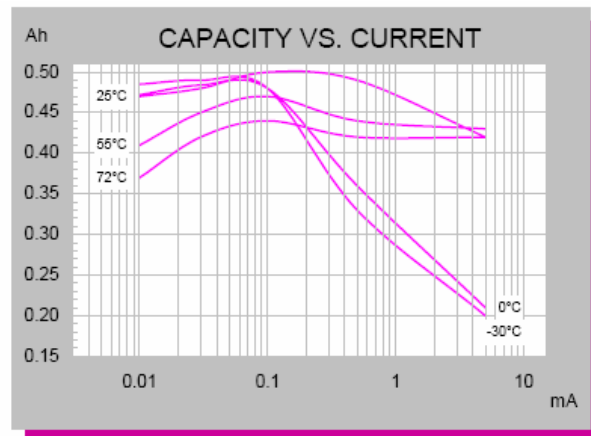
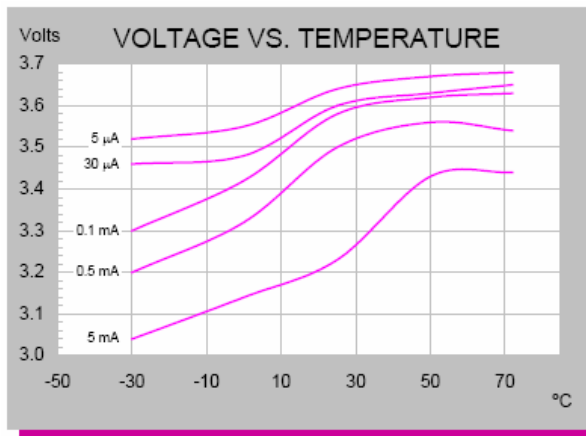


Electrochemical System	Lithium thionyl Chloride
Nominal capacity @ 0.1 mA, to 2V	0.5 Ah
Rated voltage	3.6 V
Maximum recommended continuous current	5 mA
Maximum 1 sec. pulse capability	10 mA
Weight	8.8g (0.310 oz)
Volume	2.60 cc
Operating temperature range	-55°C to + 125°C
U.L. Component Recognition MH 12193	



**ADDITIONAL INFORMATION**

SUFFIX: /P      TIN PLATED NICKEL PINS  
 CATALOGUE NO.:      15-2450-41000



**Battery testing result (compare Orange V.S other competitors)**

Test No.: 52/01

- Climatic Precondition:



2 cells of each type were preconditioned  
 during 30 days ( -40°C, 4hr.; +90°C, 4hr)  
 1 day ( -40°C, 2hr.; +120°C, 2hr)  
 4 hr. ( -40°C, 1hr.; +150°C, 1hr)  
 Cont. load: 10 KΩ (approx 300 μA);  
 Pulse load: 560Ω, 10ms (approx 5 mA), 1x/day

Discharge Temperature:  
 1 cell of each type @ +25°C  
 1 cell @ temperature cycles ( +25°C, 0°C, -5°C, -20°C, -35°C)

Each pulse was evaluated for the voltage after 10 ms  
 Results see table and diagram Ref. 5072/12

Note:  
 All cells of this test failed after been subjected to extreme temperature cycles  
 to +150°C. The failure mode of most of the cells was mechanical  
 i.e. they ruptured @ +150°C and spilled their contents.

**Test 52/01**  
**MnO<sub>2</sub> button cells for tyre pressure control systems**  
**extreme temperature cycling**

Cell No.	Manuf.	Model	Weight	Temp. cycling 1	Weight	Temp. Cycling 2	Weight	Temp. Cycl. 3	Weight	Result	Dis-charge load	Dis-charge temp.	Result	Ref.
			g		g		g		g					
				-40°C, 4 h; +90°C, 4 h; total 30 days		-40 °C, 2h; +120°C, 2h; total 1 day		-40 °C, 1h; +150°C, 1h; total 4h						
1	Panasonic	CR2450	6,5161	no	---	no	---	no	6,5160	for ref.	10 kΩ	25 °C	>0,6 Ah	5072/07
2			6,4687	yes	6,4415	yes	6,4035	yes	---	ruptured <sup>1)</sup>	---	---	failed	
3			6,4933	yes	6,4675	yes	6,4626	yes	---	ruptured <sup>1)</sup>	---	---	failed	
4	Renata	CR2450N	5,8687	no	---	no	---	no	5,8686	for ref.	10 kΩ	25 °C	0,52 Ah	5072/08
5			5,8868	yes	5,8729	yes	5,8696	yes	5,8651	self discharged	---	---	failed	
6			5,8800	yes	5,8677	yes	5,8661	yes	5,8657	OK	10 kΩ <sup>3)</sup>	cycles <sup>4)</sup>	0,01 Ah	5072/12
7	Panasonic	CR2032	3,0536	no	---	no	---	no	3,0536	for ref.	10 kΩ	25 °C	0,22 Ah	5072/09
8			3,0409	yes	3,0342	yes	3,0302	yes	---	ruptured <sup>1)</sup>	---	---	failed	
9			3,0493	yes	3,0422	yes	3,0408	yes	---	ruptured <sup>2)</sup>	---	---	failed	
10	Renata	CR2032	2,8151	no	---	no	---	no	2,8151	for ref.	10 kΩ	25 °C	0,23 Ah	5072/10
11			2,7884	yes	2,7696	yes	2,7671	yes	---	ruptured <sup>2)</sup>	---	---	failed	
12			2,7844	yes	2,7654	yes	2,7629	yes	---	ruptured <sup>1)</sup>	---	---	failed	

<sup>1)</sup> after 1 cycle @ 150 °C  
<sup>2)</sup> after 2 cycles @ 150 °C  
<sup>3)</sup> plus a pulse load of 560 Ω, 10 ms basically once per day  
<sup>4)</sup> temperature cycles +25°C / +10°C / -5°C / -20°C / -35°C (see Reference)

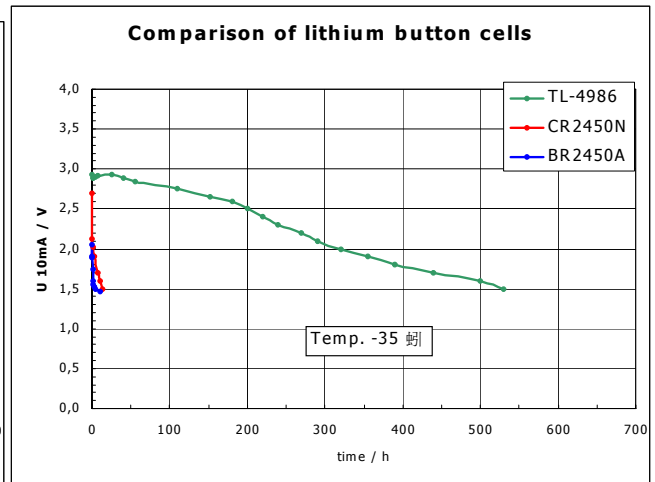
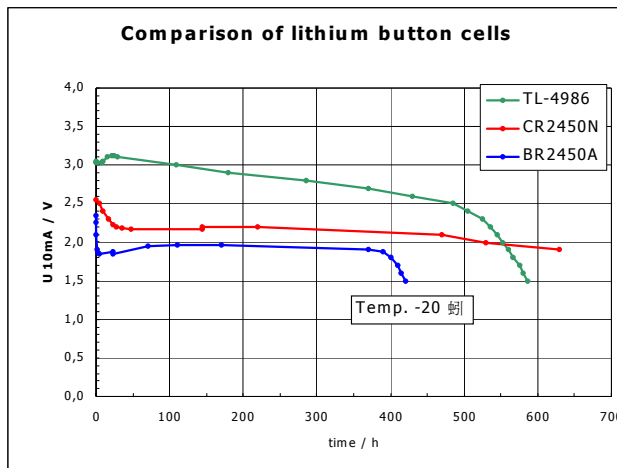
Test 02/32 - Comparison of lithium cells at low temperatures

TL-4986	lithium thionyl chloride	Orange
CR2450N	lithium manganese dioxide	Renata
BR2450A	lithium carbon fluoride	Panasonic

Basis current 0 mA, 58 s

Pulses 10 mA, 2 s

The Voltage minimum during one cycle is shown



**Conclusions:**

The CR, BR and BR-A cells are not suitable for the use in the TPMS system:

- electrically the low temperature performance is very poor.  
At – 20°C and lower the cells do not deliver the capacity and the pulse currents at the required voltage.
- mechanically both CR and BR types are weak when it comes to temperature cycles, which realistically occur inside the wheel.
- The Li/SOCl<sub>2</sub> technology, due to its composition and construction, especially the hermetic sealing (steel can, steel cover, laser welding of cover to can and glass to metal seal) meets the requirements.
- Several long term and real time tests had been conducted in the 90s, before the battery was approved by the German car manufacturers.

Examples:

- > 100000 km real time in Arizona/USA (summer)
- descent from Alp's pass (battery sees 180°C)
- safety test on 220°C for 3 hrs.



The cell was chosen by the German car industry and introduced to the market in 1997. Until to date well over a million of units are working in the field.

### 2.4. 3 Antenna design

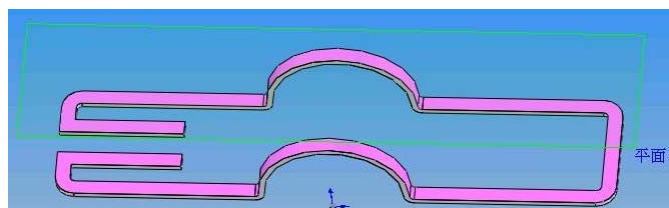
The most important element for the transmitter, which is the antenna. The antenna will influence the signal of RF transmitting, if the antenna design is not good, then the signal transmitting distance will be short, or not accurately, also will lost the power of battery. Meanwhile, if the transmitter has an optimum antenna, then it can extend the signal distance and data accurately and extend the battery life.

Therefore, the R&D center of Orange research the new function of optimum antenna. It can help the transmitter transmit the good signal to receiver, especially for OEM version. For the OEM requirement, reliability is most important, that is other competitors can not meet. Because Orange has experience for the OEM supplier for China Motor (Mitsubishi Motor Taiwan), Yu-Long Motor (Nissan Motor Taiwan) and Ford Motor Taiwan. Thus, we know what is carmaker need.

Below is Orange designing antenna, and we have applied a **patent protection**. For this antenna, Orange embedded the antenna into the housing of transmitter (figure 5), it not just only can ensure the antenna not easy broken with PCB board, but and enhance the strong signal to receiver, and increase the reliability for our product.

#### Some of advantage as below

1. Increase the antenna's area and strong signal
2. Embedded into the housing of transmitter to increase the strong structure of electronic parts.
3. Easy assemble and avoid the production line mistake happened.
4. Avoid the antenna broken after the vehicle running on the road for 5 years. (the vibration will be big in the tire, when a vehicle running)
5. Increase the battery life, because the signal strong.
6. Increase the data signal accurately and product reliability.



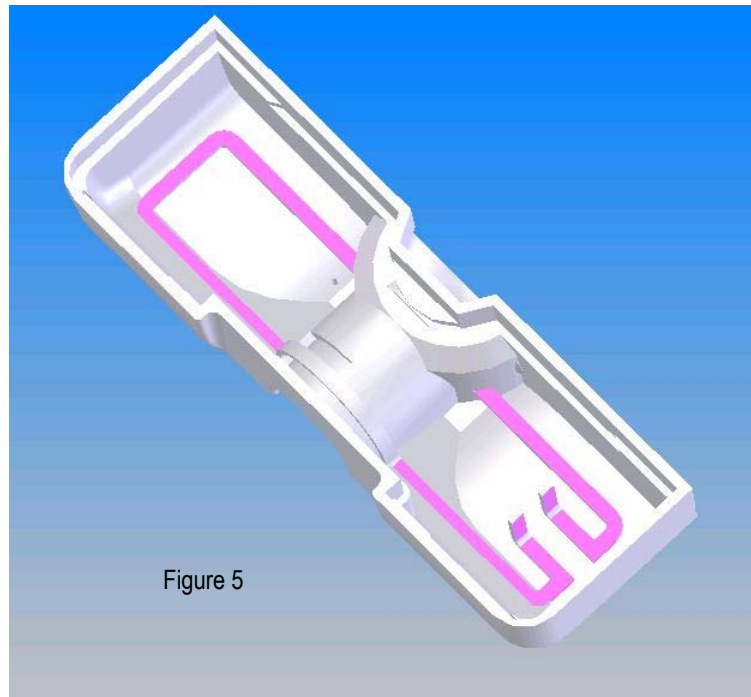
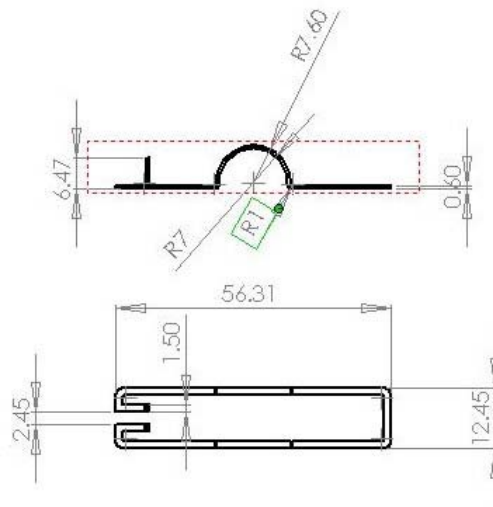


Figure 5

The antenna has embedded into the housing of transmitter; it can enhance the performance for the transmitter and this design only belongs to Orange and patent protection.



### 3 Orange v.s. Others competitors

	Orange	Other competitors	Differentiation
<b>Receiver</b>	Embedded in display and integrate check and warning function for OEM	External display box	Experienced in OEM
<b>Sensor</b>	Basic and Advance solutions	Basic solution	Orange has been test by carmaker
<b>Housing of transmitter</b>	Has reinforced the structure for housing of transmitter	Without reinforced housing, easy broken for assemble when transmitter screw in a wheel	Has been test by carmaker, and reinforced the structure in housing of transmitter, easy for assembly in carmaker
<b>Battery</b>	With 10 year battery life, and the same with BMW model	Using the normal battery, cannot meet the high/low temperature, and the battery cannot maintain longer	OEM need more battery life(at least 7years), and need to qualified by high/ low temperature. Orange's battery can meet the temperature from -40 to 120 °C, and even can up to 150°C
<b>Antenna</b>	With strong signal and embedded design, also has patent protection	Very short antenna with shorten distance transmitter, or easy broken when vehicle vibration	<ol style="list-style-type: none"> <li>1. strong structure</li> <li>2. long distance signal transmit</li> <li>3. accurately data</li> <li>4. increase battery life</li> <li>5. patent protection</li> </ol>
<b>Strong R&amp;D supporting</b>	Orange has experienced R&D center and cooperate with carmakers to perform the TPM System practicability	Most competitors only doing the aftermarket, but OEM	Experienced and qualified by carmaker, and continue invest in TPM System and related research



## **4 Conclusion**

Orange has been invest TPM system for several years, and aim to improve this system in advanced.

Therefore, Orange has owned a lot of competitive advantages to leading this market.

Moreover, Orange is one of supplier for some carmakers in Taiwan, and this TPM System has cooperated with China Motor (Mitsubishi Motor Taiwan), Yu-long Motor (Nissan Motor Taiwan) and Ford Motor Taiwan. Thus, Orange has experienced for OEM production and QC control procedure, that is the OEM take care more than others requirement. Because of the reliability of product is most important for electronic part in OEM market.

For the TPM System, Orange effort to improve more advance the art of state technology, in order to meet the OE requirement and compete with the world class competitors. Thus, Orange invest huge facilities and cooperate several R&D centers for research in various topics, which related TPM System, in order to provide our customers more advance technology and reliability products.