FTF FREESCALE TECHNOLOGY FORUM 2015

Freescale TPMS for Heavy Trucks, Buses and Construction Vehicles: More than **Monitoring Tire Pressure for Fleet Management**

FTF-INS-F1271

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External Use

Agenda

- Introduction and session objectives
- Heavy vehicles:
  Tire pressure monitoring sensor market overview
- Unique attributes of Freescale sensors
  enabling fleet management
- Sensor Data Analytics applied to fleet management
- Future trends for Freescale tire pressure
  monitoring sensors
- Conclusion
- Questions and answers

Introduction and Session Objectives

Introduction

- Freescale Semiconductor
  - Since 2013, Tire Pressure Monitoring Sensor (TPMS) Product Line Manager in Freescale's Pressure Sensor Business Unit, located in Tempe, AZ
  - **15 + years experience in MEMS Sensors**

    Marketing, Business Development, Automotive. Prior to his current assignment Francois Gilly was the Product Line Manager of the automotive inertial sensors products at Freescale

- Education
  - Engineering Degree of Electronics from l' ENSEEIHT (Toulouse, France)
  - DEA of Electronics (INP, Toulouse, France)
  - Specialized Master in Innovation and Technology Transfer (ESC/INP, Toulouse, France)

- Contact Francois Gilly at +1 480 413 8871 or email: f.gilly@freescale.com

Session Objectives

- Introduction to the heavy vehicles tire pressure monitoring system market and its key motivator: Sensor Data Analytics

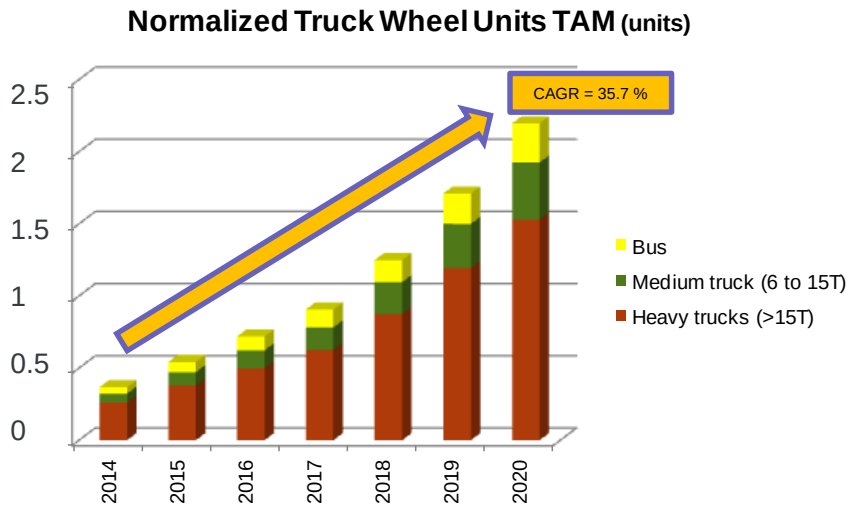
- The key attributes of the FXTH8715 family which enable the development of this market
  - Size
  - Sensing attributes
    (Pressure, Acceleration, Temperature, Battery Voltage Monitoring)
  - Memory flexibility

- Which tire pressure monitoring sensors Freescale is to develop in the future to even fit better this market

- Where to find even more information on this subject

Heavy Vehicles TPMS Market Overview

FXTH8715 Family Tire Pressure Monitoring Sensor Market Assessment



- Key markets
  - TPMS for trucks, buses and construction vehicles
- Market trends
  - Growth expected in Europe and North America to improve effectiveness of fleet management through Sensor Data Analytics
  - Growth expected in China to improve bus safety
- Key buying factors
  - Product availability
  - Solution size
  - Easy to implement (transfer from previous solutions and FAE support)
  - Solution robustness
  - Application cost savings

Tire Pressure Monitoring Module Implementation in Heavy Vehicles

Modules installed on the valve stems

- Rim or valve stem mounted
- Pressure and temperature sensing
- Roll switch, wheel localization
- Battery operated
- Independent from the tires

Modules installed on the tire treads

- Tire mounted sensors
- Pressure, temperature, radial and tangential tire acceleration
- Battery operated or battery less
- Linked to the tire

Modules installed on the tip of the valves

- Sensors mounted on top of the tire valves
- Pressure, temperature, radial tire acceleration
- Battery operated
- Common in aftermarket solutions

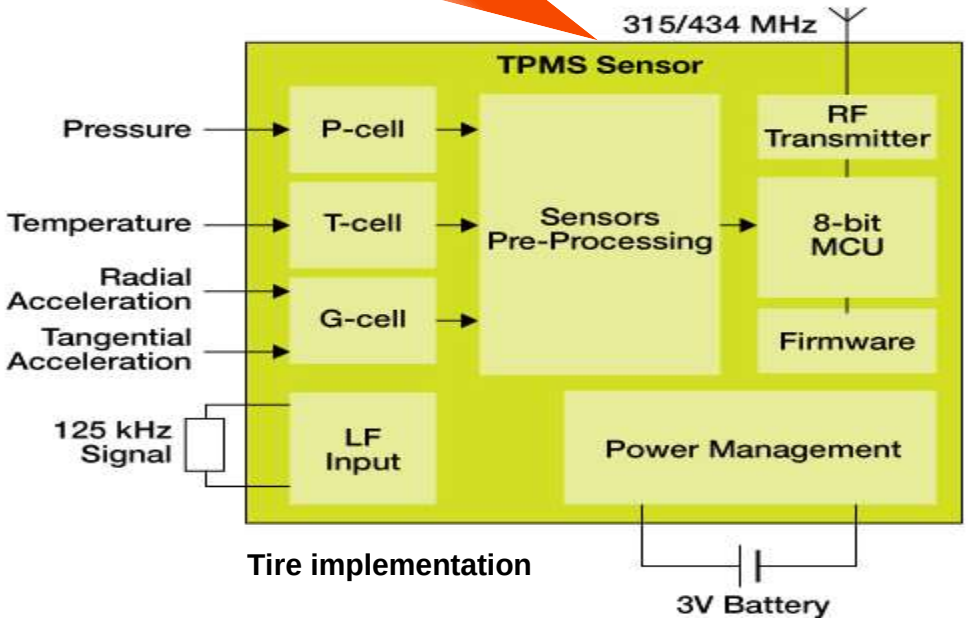
Unique Attributes of Freescale Sensors Enabling Fleet Management

The FXTH8715 TPMS Family

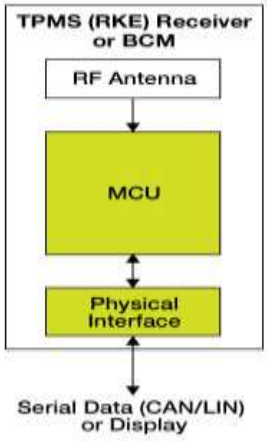
- On October 20th, 2014 Freescale introduced the World's smallest integrated tire pressure monitoring sensors in QFN 7x7 for light vehicle applications with a pressure range of 100-450 kPa or 100-900 kPa
- Now Freescale is proposing an extension of its portfolio to enable heavy trucks, buses and construction vehicle tire pressure monitoring applications

Freescale FXTH87 TPMS Integration

QFN 7x7 Cross-section illustration



Tire implementation



Vehicle implementation

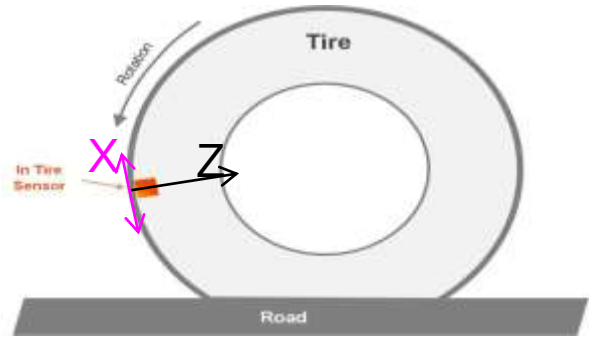
FXTH87 Family Extended Reliability Testing Results

- The TMPS 7x7 family was fully qualified per the Freescale qualification standards as well as AEC-Q100-Rev-G guidance

- To validate even further the TPMS7x7 robustness, Freescale has performed a test to fail at **4x AEC stress conditions.** All tests completed with no failures.

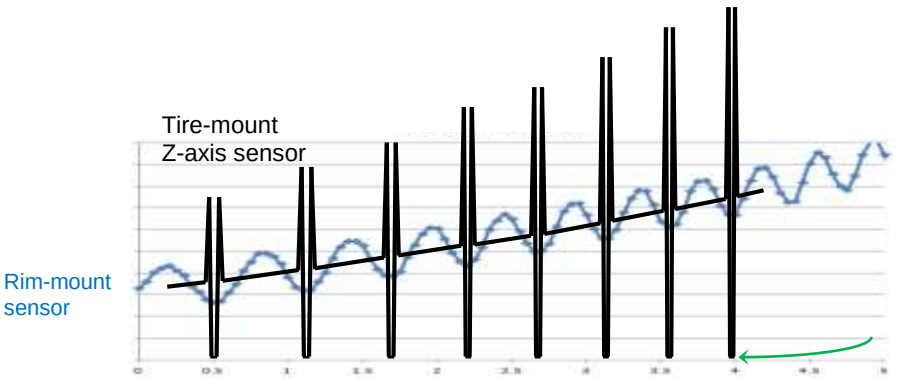
Test	Conditions
HTOLP (High Temperature Operating Lifetime, pressure)	4032 hours
THB (Temperature, Humidity, Bias)	4032 hours
TC (Temperature cycles)	4100 cycles
Thermal Shock	3000 cycles
RDE (Rapid Decompression Event)	40 cycles
Centrifuge	3500g, 15 min

Application Challenges When Module is Installed on Tire Tread



Z: radial acceleration
X: tangential acceleration

Peaks of acceleration of around 3000 g



- Very high mechanical stress (up to 2 shocks per rotation) with potential impact on accelerometer, wires and package
- Temperature extreme (cold start to self heating from driving to high speeds)
- Liquid/sand/dust in tire over temperature and g-force
- Customer install: full understanding of installation procedure

FXTH87 Characterization Results When Module is Installed on Tire Tread

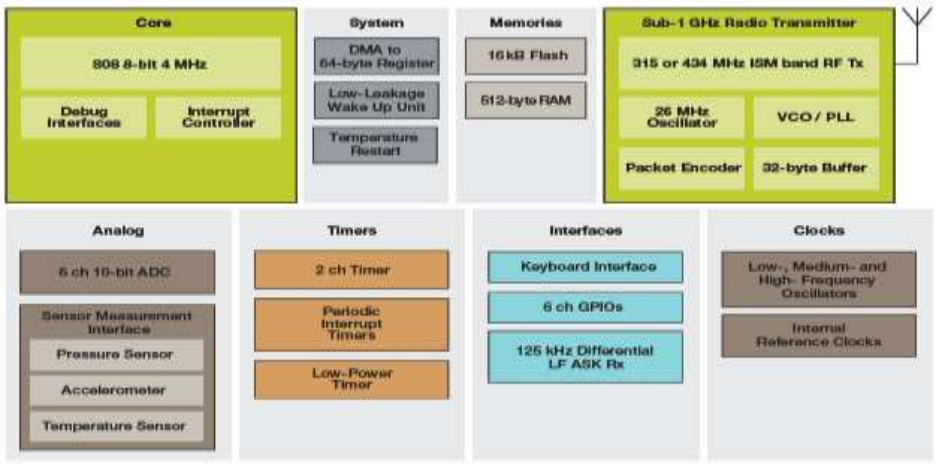
Characterization	Results
Wire Motion Modeling	Deformation of the gold wire at the peak impact event is less than 1 micron in any case and NOT critical even without GEL
G-cell Z-axis motion simulation	DC negative acceleration clipping for Z-axis = -719 g which corresponds to ~160kph with a tire type 195x40 R16. Standard deviation is 38g when taking into account process variation.
Rotation by 90° of the module inside the tire	FEA model run with 1000g applied in the X direction shows displacement at the stop smaller than the primary stop gap
G-cell Z-axis electrostatic shock characterization	No stiction, no drift of clipping voltage and no drift of capacitance or range of motion (within tester capability) observed after around 99 millions of shocks.
Centrifuge Emulation (2600g / 3000g / 3500g)	3 lots x 6 samples - 15mn each. No stiction, no drift of clipping voltage and no drift of Capacitance or Range of motion observed (within tester capability) Centrifuge emulation generated no mechanical damage to the units
High Speed stress test	3 lots x 30 samples. No significant output deviation before PCB mounting, after stress tests (5 temp) and after martini test (25°C) Failure analysis on 2 good stressed parts + 1 unstressed part did not reveal any G-cell anomalies
Endurance test	3 lots x 30 samples. No significant output deviation before PCB mounting, after stress tests (5 temp) and after martini test (25°C) Failure analysis on 2 good stressed parts + 1 unstressed part did not reveal any G-cell anomalies

FXTH8715 TPMS Family Robustness Demonstration

- The FXTH8715 TPMS family is fully qualified per the Freescale qualification standards as well as AEC-Q100-Rev-G guidance
- In addition to media compatibility requirements dedicated to light vehicles, the FXTH8715 family successfully passed additional media exposures more specifically required in European truck implementations:

Test Conditions	Qualification Criteria
Brake Fluid (Havoline Heavy duty Dot-3 FMVSS 116 ISD 4925), SEA J1709 Method: Pressurized syringe/needle method	Zero Electrical Test Failures at 25C, 125C or -40C
Refreshment containing caffeine and sugar (CocaCola), ISO 16-750-5: ID ED + EE, 24 h@ room Method: Pressurized syringe/needle method	Zero Electrical Test Failures at 25C, 125C or -40C
Acetone, ISO 16-750-5: ID DG, 24 h@ room Method: Pressurized syringe/needle method	Zero Electrical Test Failures at 25C, 125C or -40C
Tire gases (Pure Helium), 24 h@ room, 300 kPa Method: Immerse in container	Zero Electrical Test Failures at 25C, 125C or -40C
Tire gases (Pure Nitrogen), 24 h@ room, 300 kPa Method: Immerse in container	Zero Electrical Test Failures at 25C, 125C or -40C
Rim cleaner (Mercedez Benz), room temp Method: Pressurized syringe/needle method	Zero Electrical Test Failures at 25C, 125C or -40C
AdBlue (urea) Method: Pressurized syringe/needle method	Zero Electrical Test Failures at 25C, 125C or -40C

FXTH8715 Family Key Benefits



In Production Now

- Highest level of integration
  - Up to 1500 kPa pressure sensor
  - 1-/2-axis accelerometer
  - MCU with 315/434 MHz RF transmitter and LF receiver
- Compact and light weight
  - 7 x 7 x 2.2 mm, 0.3g
  - Enable weight and space constrained TPMS modules
- Single and dual axis accelerometer
  - Easy after market installation
  - Support all tire localization methods
- 8 kB flash for customer application
  - Enable differentiated module features

What is Sensor Data Analytics ?

- **Sensor Data Analytics** is the science of examining raw data with the purpose of uncovering insights and drawing conclusions (examples: consumer purchasing history, website browsing pattern, etc..) to
  - better understand consumer needs
  - sharpen companies' targeting efforts

- This science can now be applied to raw sensor data. This is what we call "**Sensor Data Analytics**"

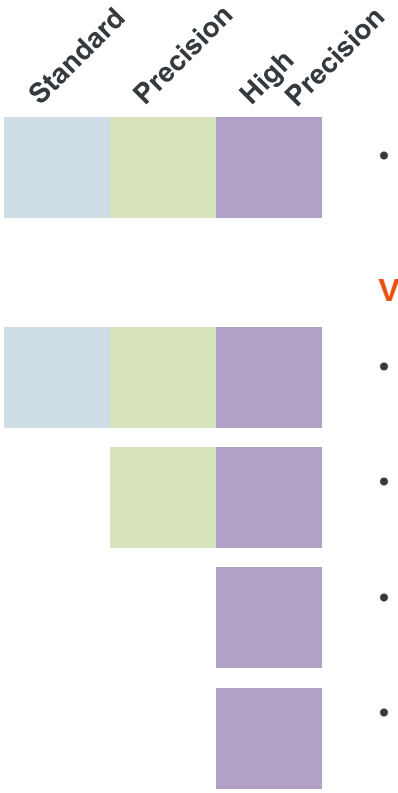
Ordering Information: FXTH8715xx 1500kPa Portfolio

Part Number	Pressure Range (kPa)	Pressure accuracy ($0^oC \le T_A \le 70^oC$)	Temperature Range (^oC)	Temperature accuracy ($0^oC \le T_A \le 70^oC$)	Z-axis Accelerometer Range (g)	Z-axis Accel accuracy ($0^oC \le T_A \le 70^oC$)	X-axis Accelerometer Range (g)	X-axis Accel accuracy ($0^oC \le T_A \le 70^oC$)
Standard Tolerances								
FXTH871502**D**T1	100-1500	±20 kPa	-40 to 125	±3^{o}C	-270 to 400	±6g	--	--
FXTH871511**D**T1					-210 to 300	±5g	-80 to 90	±4g
Precision Tolerances								
FXTH871502**6**T1	100-1500	±20 kPa	-40 to 125	±3^{o}C	-270 to 400	±3g	--	--
FXTH871511**6**T1					-210 to 300	±3g	-80 to 90	±3g
High Precision Tolerances								
FXTH871502**7**T1	100-1500	+/- 17 kPa	-40 to 125	±3^{o}C	-270 to 400	±3g	--	--
FXTH871511**7**T1					-210 to 300	±3g	-80 to 90	±3g

Sensor Data Analytics Applied for Fleet Management

Heavy Vehicle Fleet Management Requirements

- Fleet management optimization revolves around 4 main axes:

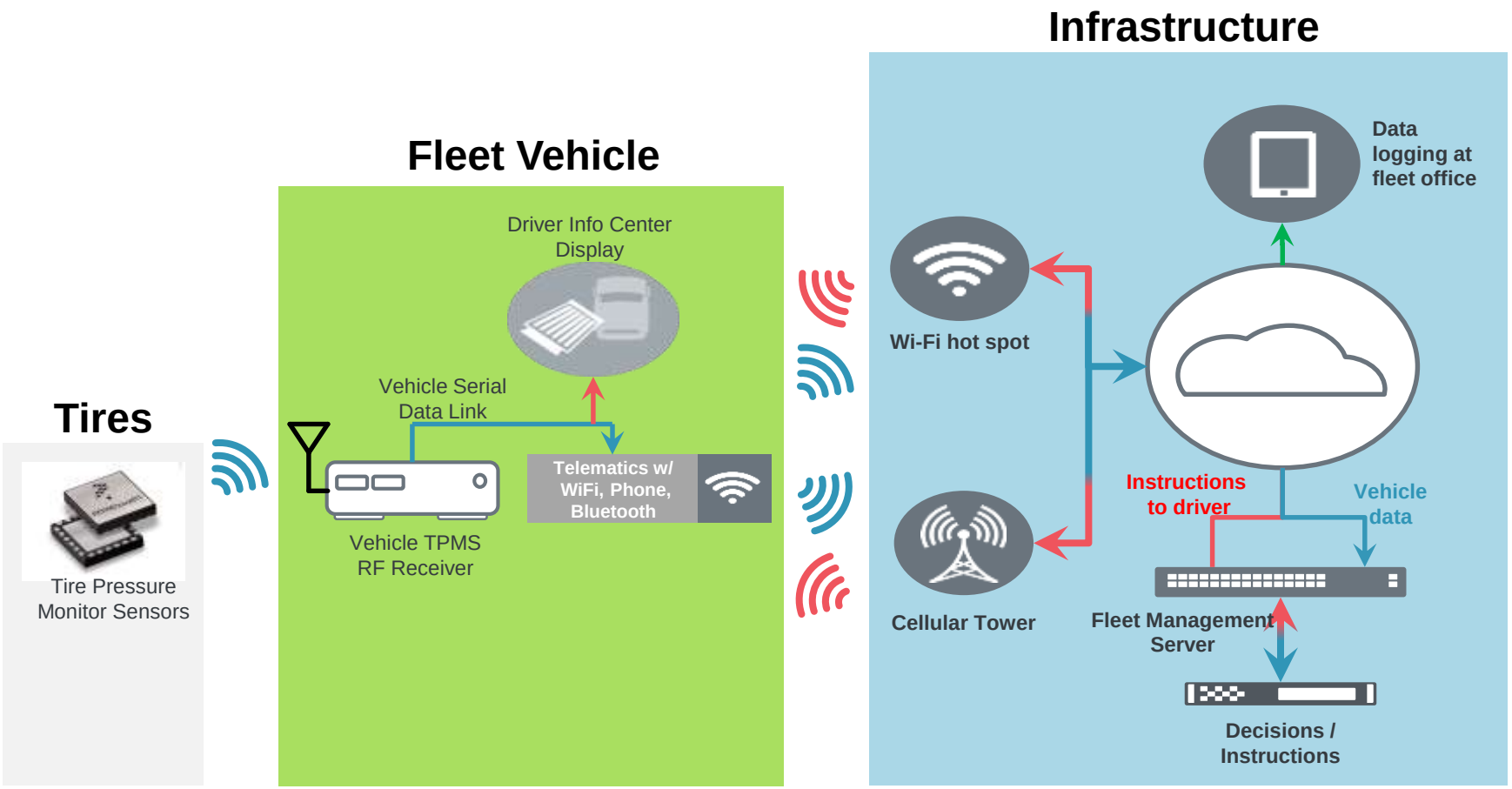


- **Basic Safety requirement: Low Pressure Light Warning**
  Warn the driver of large pressure variation or below a pre-defined threshold.

Valued requirements (Sensor Data Analytics):

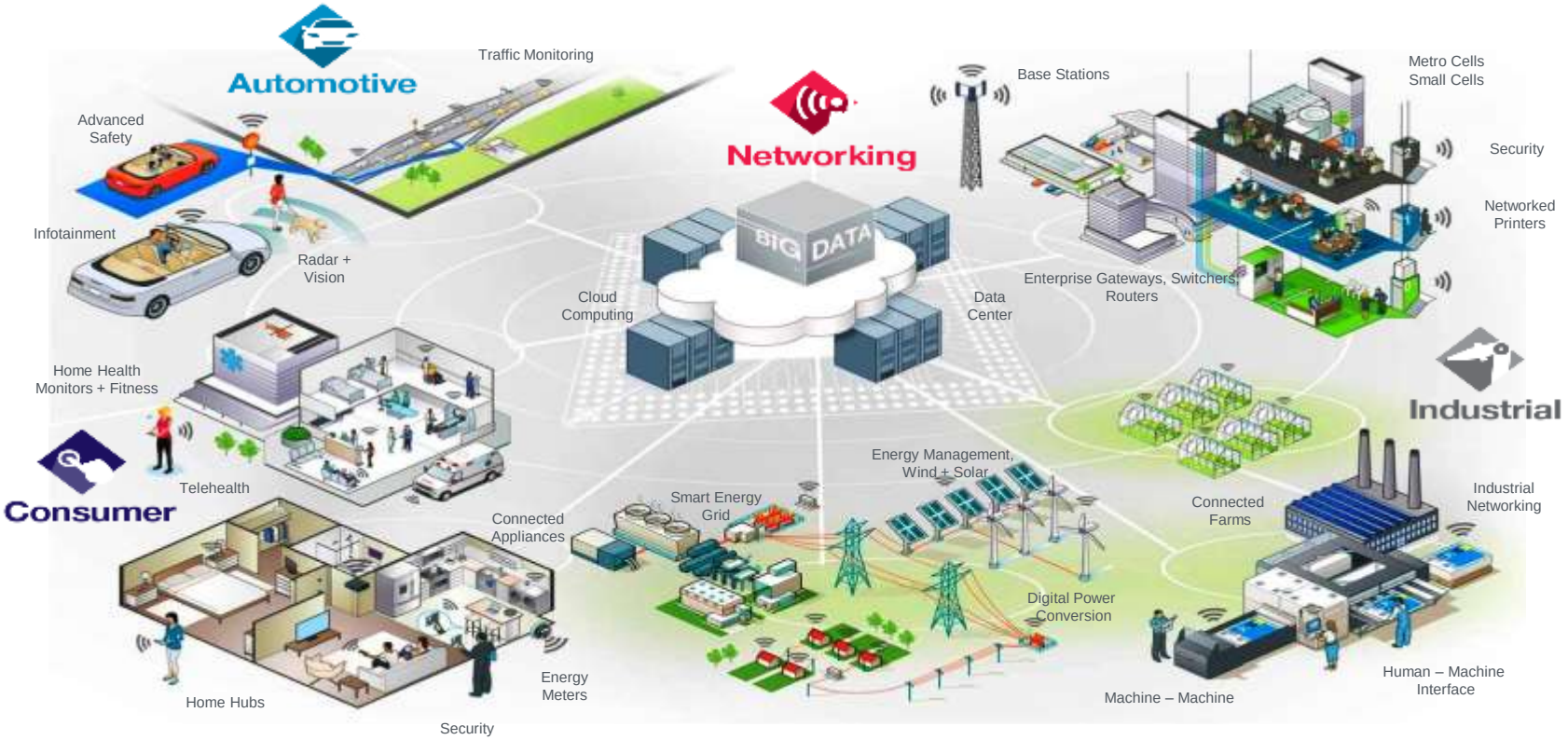
- **Tire health prognostic**
  Temperature or pressure excursions can be an indicator of tire life becoming compromised
- **Automated Position determination**
  Precision accelerometers assist driver / service provider to ID which position a suspect tire is located
- **Fuel /Oil economy**
  High precision pressure accuracy supports optimal rolling resistance and reduced engine load
- **Maintenance interval prognostics**
  High precision pressure accuracy supports a prediction of the leak rate, thus maintenance scheduling at a convenient time and long before a safety issue may arise.

Fleet Management Sensor Data Analytics



Our Products Power the Internet of Things

Microcontrollers | Digital Networking | Auto MCU | Analog and Sensors | RF

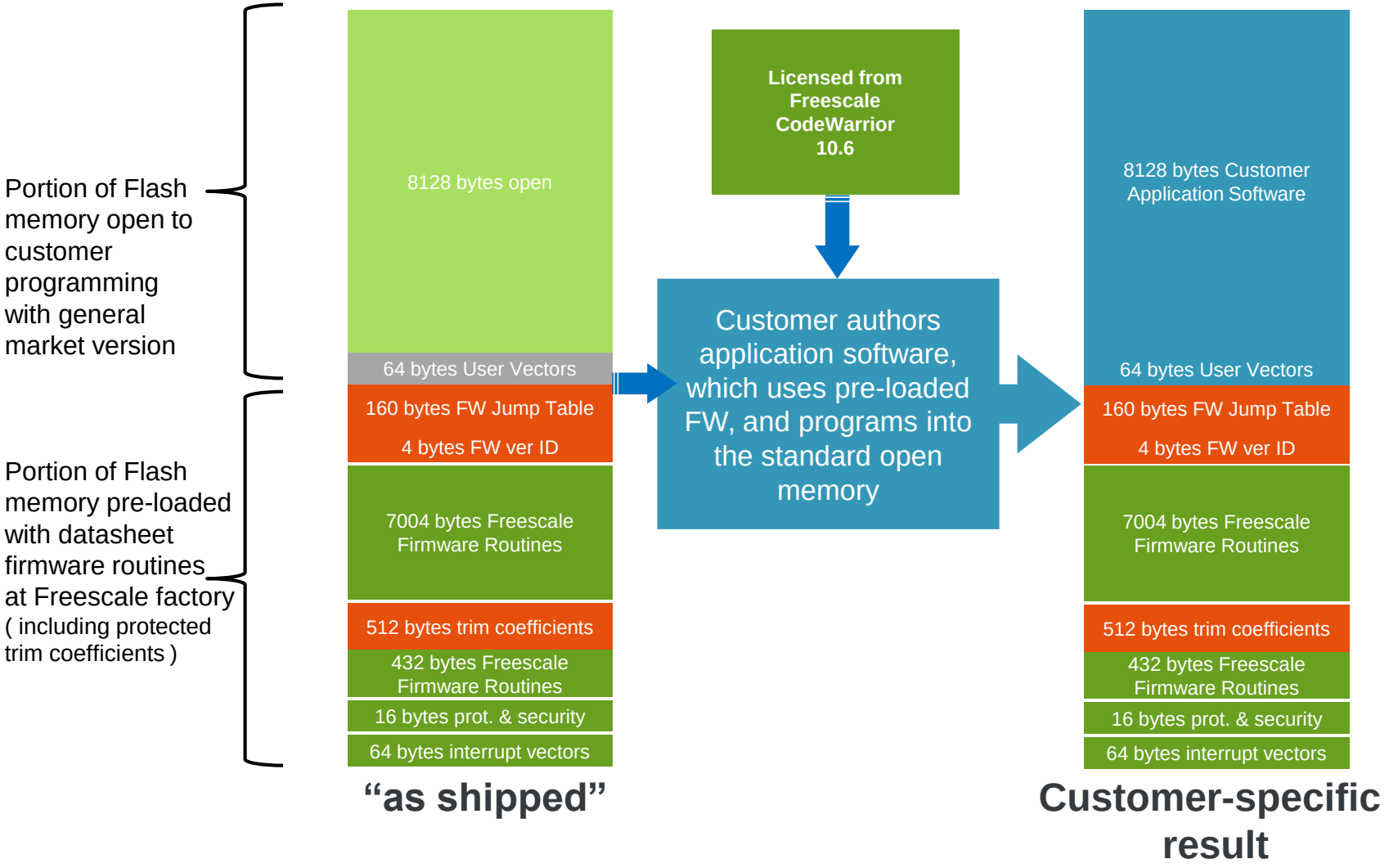


We Have a **Broad Portfolio**

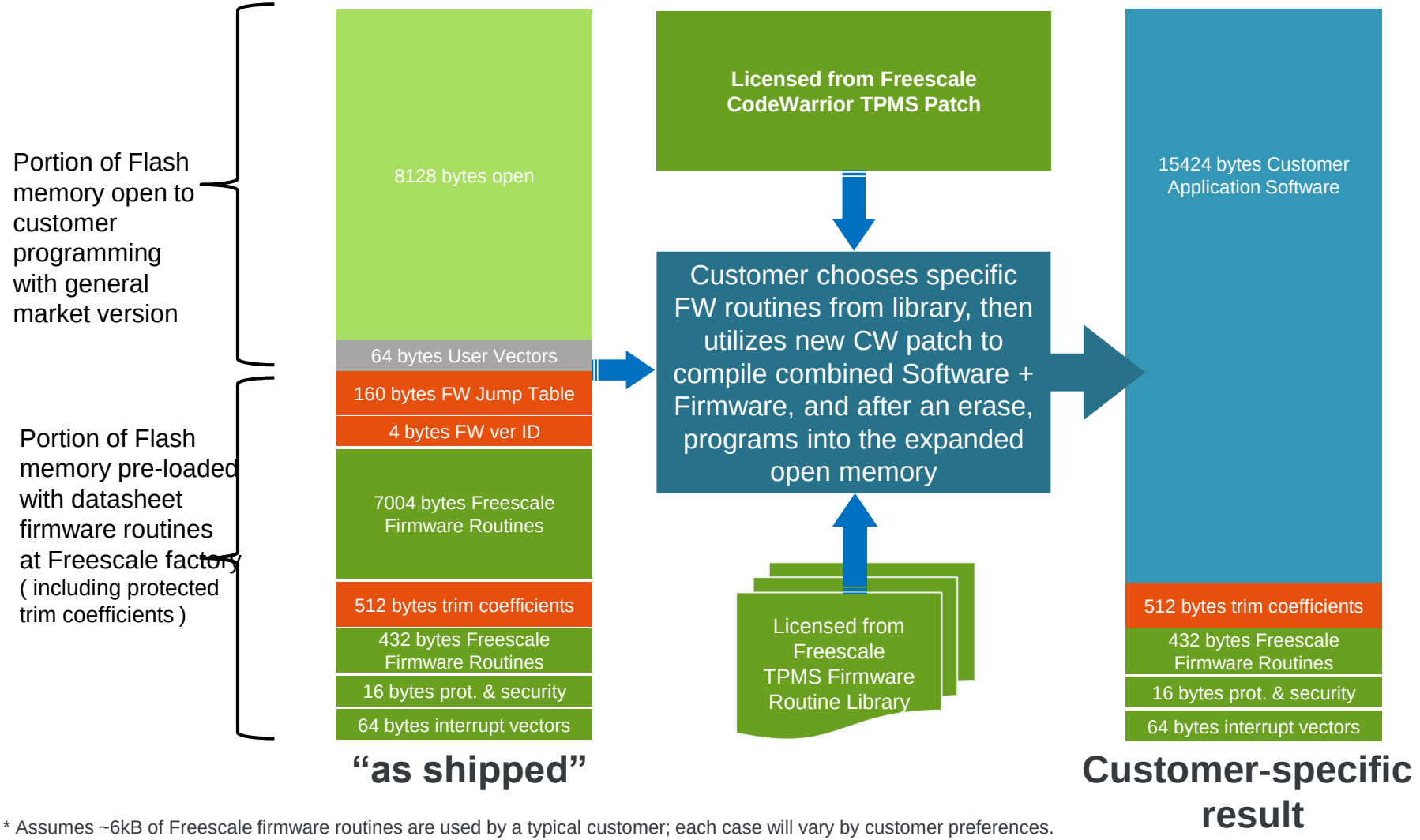
How the FXTH8715 Family Enables Sensor Data Analytics

- Above its sensing characteristics, the FXTH8715 family also enables more software implementation flexibility through a possible increase of its customer dedicated FLASH
- By selecting only the routines needed for specific applications additional FLASH can be made available for new functions such as:
  - **Tire health**, for example: Abuse detection (acceleration, pressure, temperature)
  - **Life expectancy** prediction (pressure, temperature)
  - **Security:** software could enable encryption for sensitive fleet management data
  - **Fuel economy:** thanks to the sensor accuracy, the software can provide more precise end-user advice while optimizing module battery life
  - **Rotation Counter** (acceleration) : software could enable creation of a tire specific odometer by marrying the tire ID to the sensor ID and counting rotations

Standard Flash Memory: ~8kB



Expanded Flash Memory: ~10kB*



* Assumes ~6kB of Freescale firmware routines are used by a typical customer; each case will vary by customer preferences.

FXTH8715 Eco-System

- **Evaluation Boards:** emulate typical customer wheel unit module contai sensor, LF coil, RF antenna, battery, and all passives
  - TPMS871511-315 (1500 kPa – 315 MHz)
  - TPMS871511-434 (1500 kPa – 434 MHz)

- **Application Notes / Reference Manuals for FXTH87 TPMS family**
  - **FXTH87EDRM:** FXTH87 Family Evaluation Design Reference Manual
  - **FXTH87XX22FWUG:** FXTH87xx22 Embedded Firmware User Guide
  - **AN4277:** Interfacing to Freescale's FXTH87xx In-Flash Firmware Routines Using C-language Constructors
  - **AN4391:** Using the FXTH87 Family of LF Receivers for TPMS Application
  - **AN1902:** Assembly Guidelines for QFN and DFN Packages to cover the QFN7x7mm packages
  - **AN5136:** Applying the Kinetis MKW01 as the receiver for the FXTH87 Tire Pressure Monitoring Sensor.

- **General support topics:**
  - **Assistance with implementing a wireless (LF/RF) boot-loader** to re-program customer application memory space.
  - **Assistance with selectively increasing customer application memory space** with the FXTH8715117T1 and FXTH8715027T1.
  - **Assistance with tuning RF matching network** to suit customer specific antenna choices

For further information please refer to: www.freescale.com/TPMS

Future Trends for Freescale Tire Pressure Monitoring Sensors

Future Trends for Freescale Tire Pressure Monitoring Sensors

- Become more energy efficient
  (extend battery life and/or enable the use of smaller batteries)

- Become even smaller
  (enable more cost effective solutions)

- Pending market requirements, integrate energy harvesting capabilities

Related Session Resources

Session ID	Title
FTF-ACC-F1267	Big Data Applications for the Connected Car
FTF-IND-F1279	How to Use the RF Power Tool System to Enable Non-traditional RF Customers
FTF-INS-F1124	Monetizing Sensor Data: Uncovering Valuable Information from Raw Sensor Data
FTF-INS-F1220	**Hands-On Workshop:** Sensor Data Collection and Mining: Intelligent Data Loggers, Part 1 of 3 (Reserved Seat Required)
FTF-INS-F1221	Hands-On Workshop: Sensor Data Collection and Mining: Mining Individual Sensor Data in the Time-Domain, Part 2 of 3 (Reserved Seat Required)
FTF-INS-F1222	**Hands-On Workshop:** Sensor Data Collection and Mining: Mining Individual Sensor Data in the Frequency-Domain + Mining Data Using Sensor Fusion, Part 3 of 3 (Reserved Seat Required)
FTF-INS-F1126	Sensor Data Collection and Processing for Sensor Data Analytics Overview, Part 1
FTF-INS-F1127	Sensor Data Collection and Processing for Sensor Data Analytics: Using Processor Expert and ISF to Create an Embedded Data Logger, Part 2
FTF-INS-F1263	Panel: The Connected Car – A Wireless Gateway for Unlimited Information for V2V and V2I Applications

Related Demo Resources

Pedestal ID	Demo Title
A13	1500 kPa range Tire Pressure Monitoring Sensor (TPMS)
Z20	Water Pump Condition Monitoring
P75	KegData monitoring with Freescale Pressure Sensors
W5	Sensor Fusion Development Kit
P74	Intelligent Stovetop
A5	77 GHz Radar Using Fast Modulation Technology

Conclusion

www.Freescale.com