AUTOMOTIVE SENSORS OVERVIEW

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SECURE CONNECTIONS
FOR A SMARTER WORLD

Safe & Secure Mobility – 90% Innovation Through Electronics

Seamlessly Connected Mobility Experience

One hour per day in the vehicle

Enjoying Life

ADAS Towards Self-Driving

1.3M global road fatalities every year

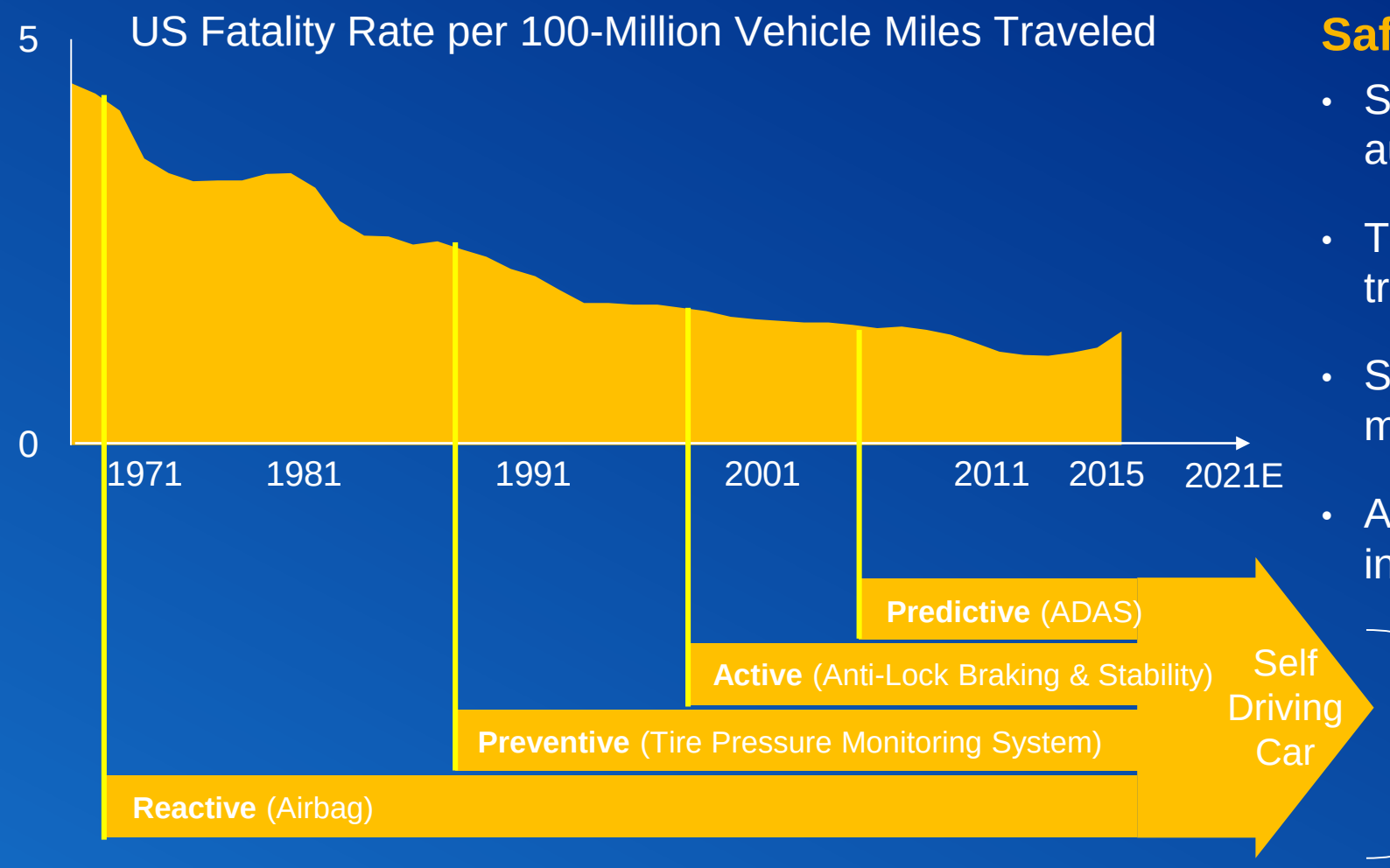
Saving Lives

Energy Efficiency

US mandates 163 grams / mile and 54.5 MPG by 2025

Reducing CO_2

Safety Advancements Reducing Road Fatalities



Safety crucial for self-driving car

- Safety, quality & reliability at the heart of automotive engineering
- Trusted technology and functional safety track-record essential
- Safety system adoption accelerated by mandates & NCAP ratings
- ADAS needed to reverse recent increase in fatality rate (texting)

BL Sensor Core Markets

BL Sensors: Introduction

Automotive Sensors as a Foundation to Safety & Highly Autonomous Driving

Motion Sensor

Airbag Accelerometers, Active Safety Combos & IoT

- All passive safety Tier-1's using NXP
- Next generation discrete & integrated UMEMS foundational for Auto & IoT future
- Active safety motion sensors (gyro+accel)

Pressure Sensors

TPMS, Engine Mgnt, Medical & Airbag Satellite Pressure

- Investing lowest power, smallest size solutions
- High accuracy pressure - flow measurements
- Complementing airbag-motion solutions

Magnetic Sensors

Angular for Engine Control ABS Speed Sensors

- Angular sensors: engine control & steering
- Speed wheel sensors for ABS
- AMR→TMR transition foundational for long term revenue growth & EBIT expansion

#1 in Automotive Safety Sensors

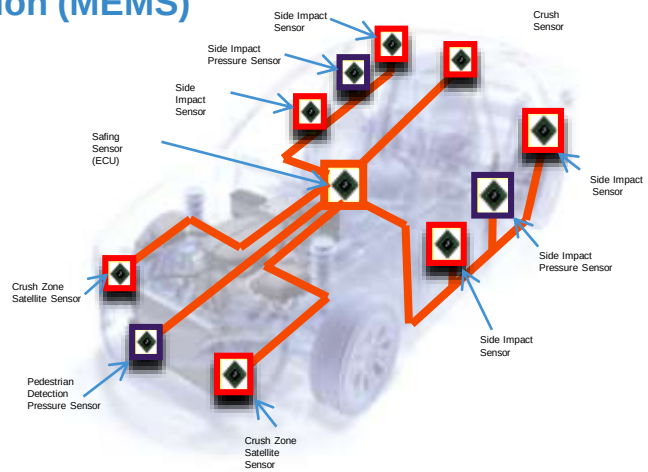
Key MEMS Figures

- More than 3.0 billion MEMS sensors shipped
- **1.5 billion** MEMS sensors shipped in automotive applications
  - **1.2 billion** Airbag sensors
  - **140 million** pressure sensors for engine mgmt
  - **75 million** tire pressure sensor
  - **50 million** pressure sensor die

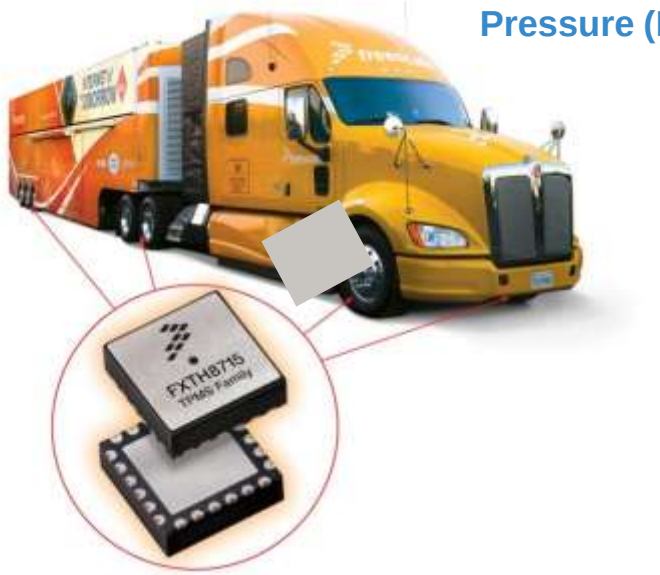
- Shipping 300 million MEMS sensors annually*, **200 million are going into automotive applications**

- **1 billion** Magnetic (MR) Sensors

Motion (MEMS)



Pressure (MEMS)



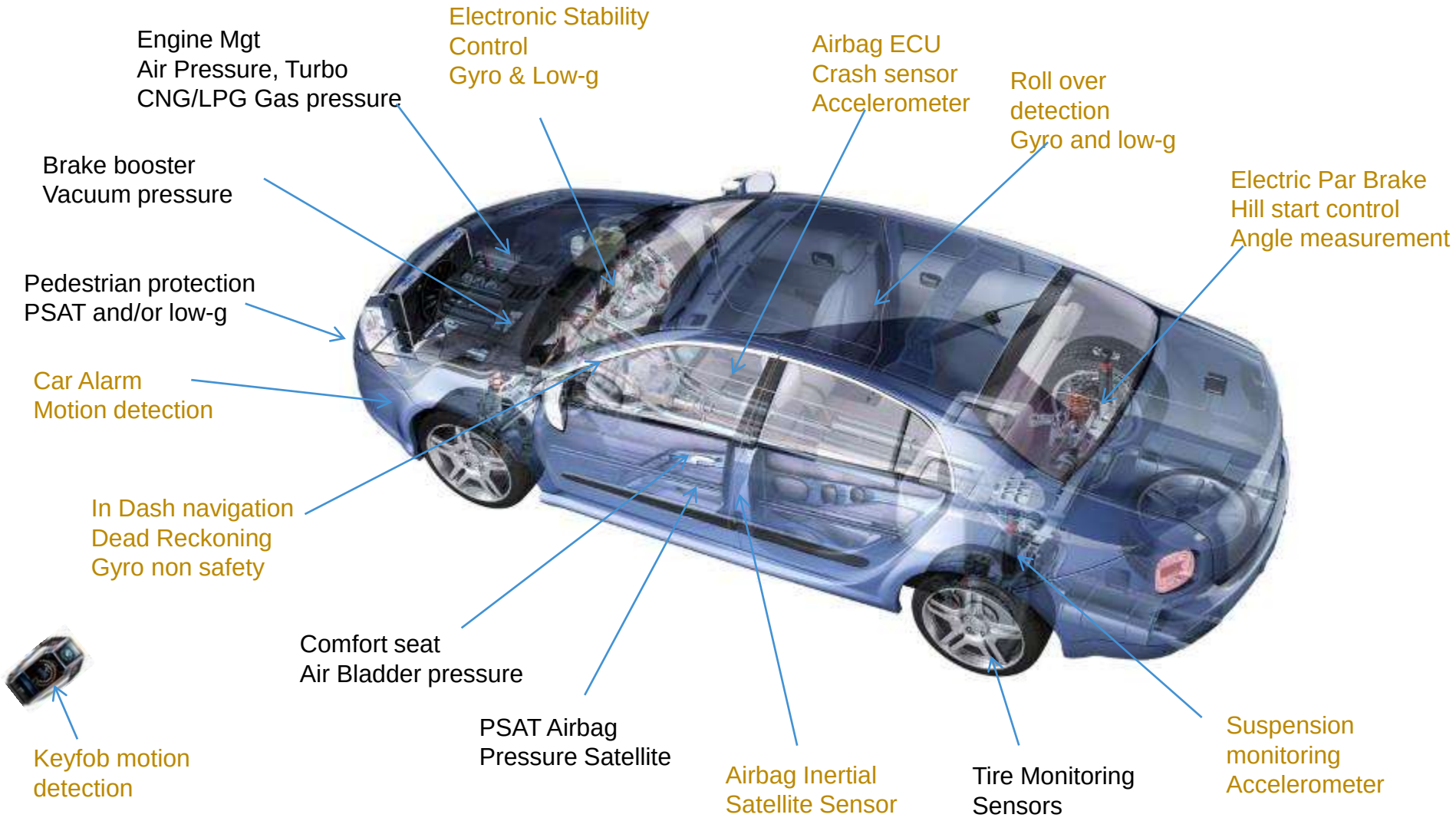
AGENDA

- Automotive sensors overview
  - Motion sensors
  - Pressure sensors
  - Magnetic sensors
- Q&A

01.

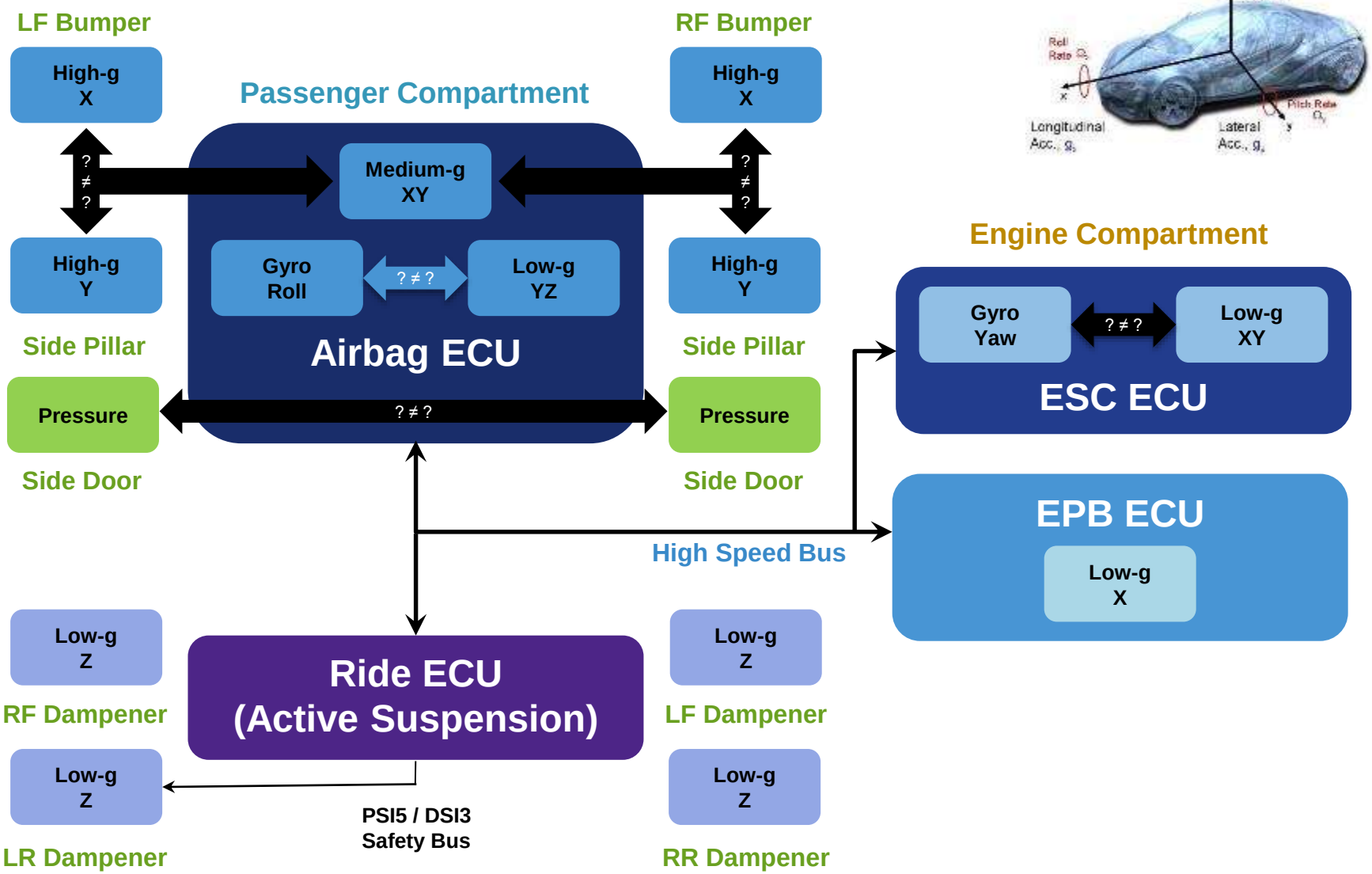
Motion Sensors

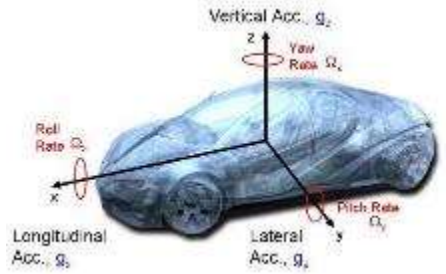
NXP MEMS Sensors in Automotive Applications



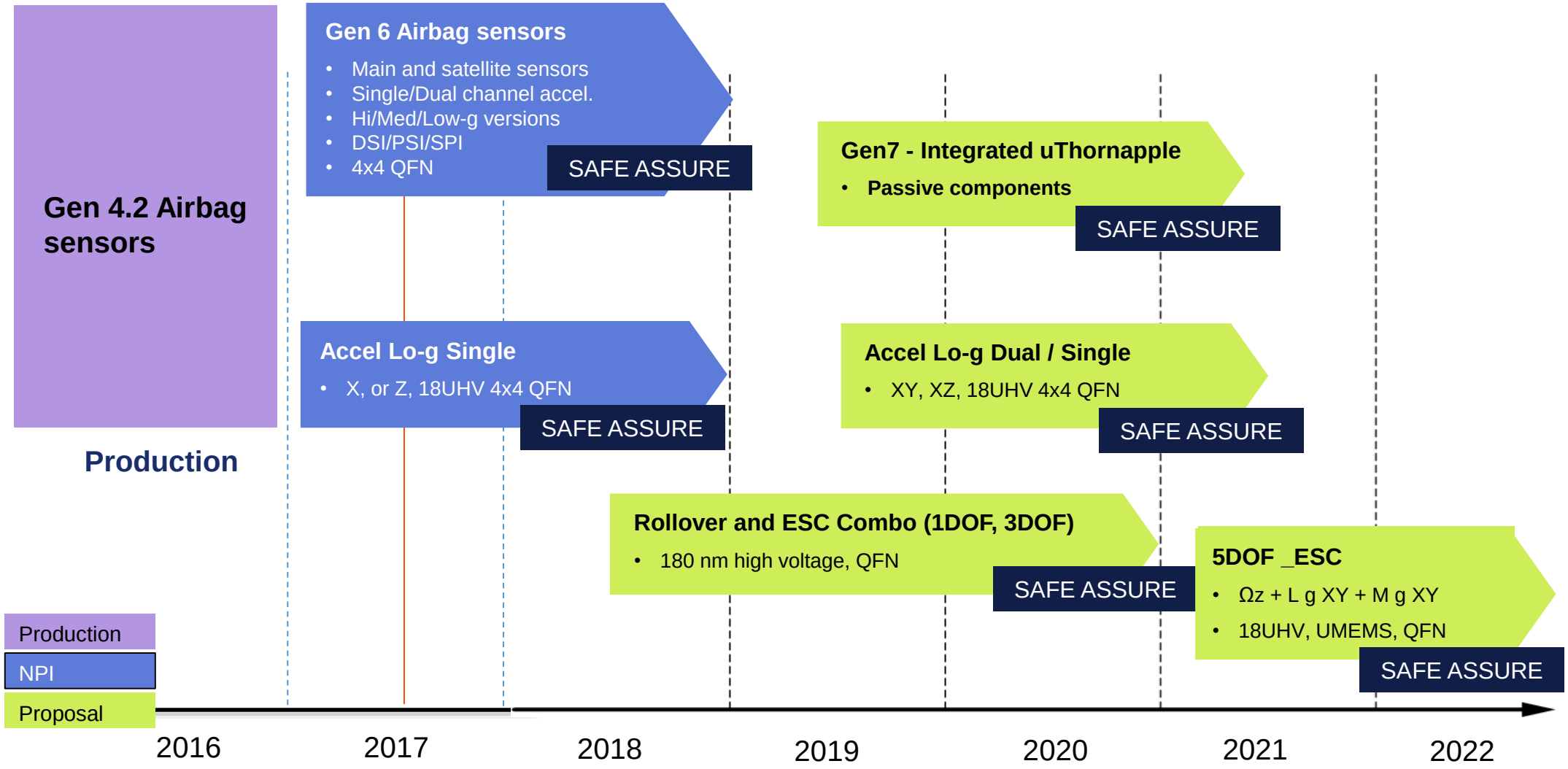
MOTION SENSORS APPLICATIONS AND ROADMAP

NXP Solution in Current Architecture





Automotive Sensor Product Roadmap Overview



ACCELEROMETERS

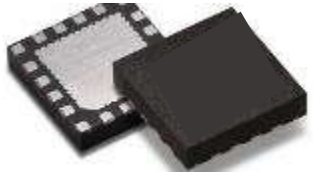
Current Production Automotive Accelerometers (Gen 4)

MMA26xx / MMA16xx

- Digital Output
  - DSI 2.5 compliant
- G range:
  - ±50 g to ±312.5 g
- Axis
  - X-axis, or Z-axis
- Selectable LPF
- QFN 6x6 package
- Operating temp:
  - -40C to 125C

MMA52xx / MMA51xx

- Digital Output
  - PSI5
- G range:
  - ± 60g to ± 480g
- Axis
  - X-axis, or Z-axis
- Selectable LPF
- QFN 6x6 package
- Operating temp:
  - -40C to 125C

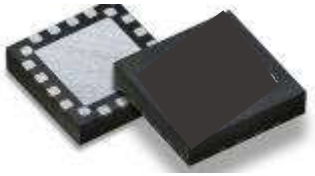


MMA27xx / MMA17xx

- Digital Output
  - DSI3
- G range:
  - X-Axis 25g, 125g, 187g, 250g and 375g
  - Z-Axis 250g
- Selectable LPF
- QFN 6x6 package
- Operating temp:
  - -40C to 125C

MMA65xx / MMA6555x

- Digital Output
  - SPI
- G range:
  - ± 20g to ± 120g
  - ± 80g to ± 120g
- Axis
  - XY-axis
- Arming function
- Selectable LPF
- QFN 6x6 package
- Operating temp:
  - -40C to 125C



MMA69xx

- Digital Output
  - SPI
- G range:
  - ± 3.5g or ± 5.0g
- Axis
  - XY-axis
- QFN 6x6 package
- Operating temp:
  - -40C to 105C

Gen6 Project Scope – Covering All Airbag Requirements

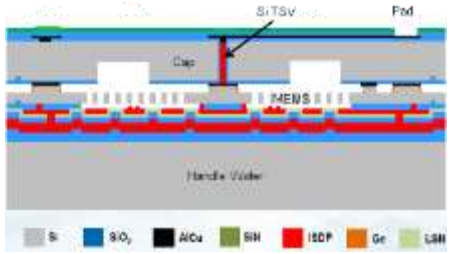
- **15 UMEMS variation designs**
  - Three g-ranges (low, med, high)
  - Three orientation (x, y, z)
- **2 ASIC designs (LL18UHV)**
  - Single channel PSI5/DSI3/SPI
  - Dual channel PSI5/DSI3/SPI
- **1 package type**
  - QFN 4x4 mm

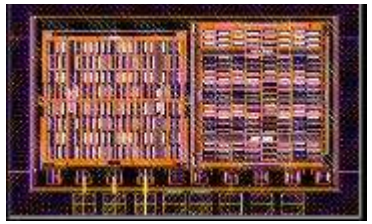
- **4 core projects**
  - Single Chanel Med/High
  - Dual Channel Med/High
  - Accel Low G single
  - Accel Low G dual

Product Matrix

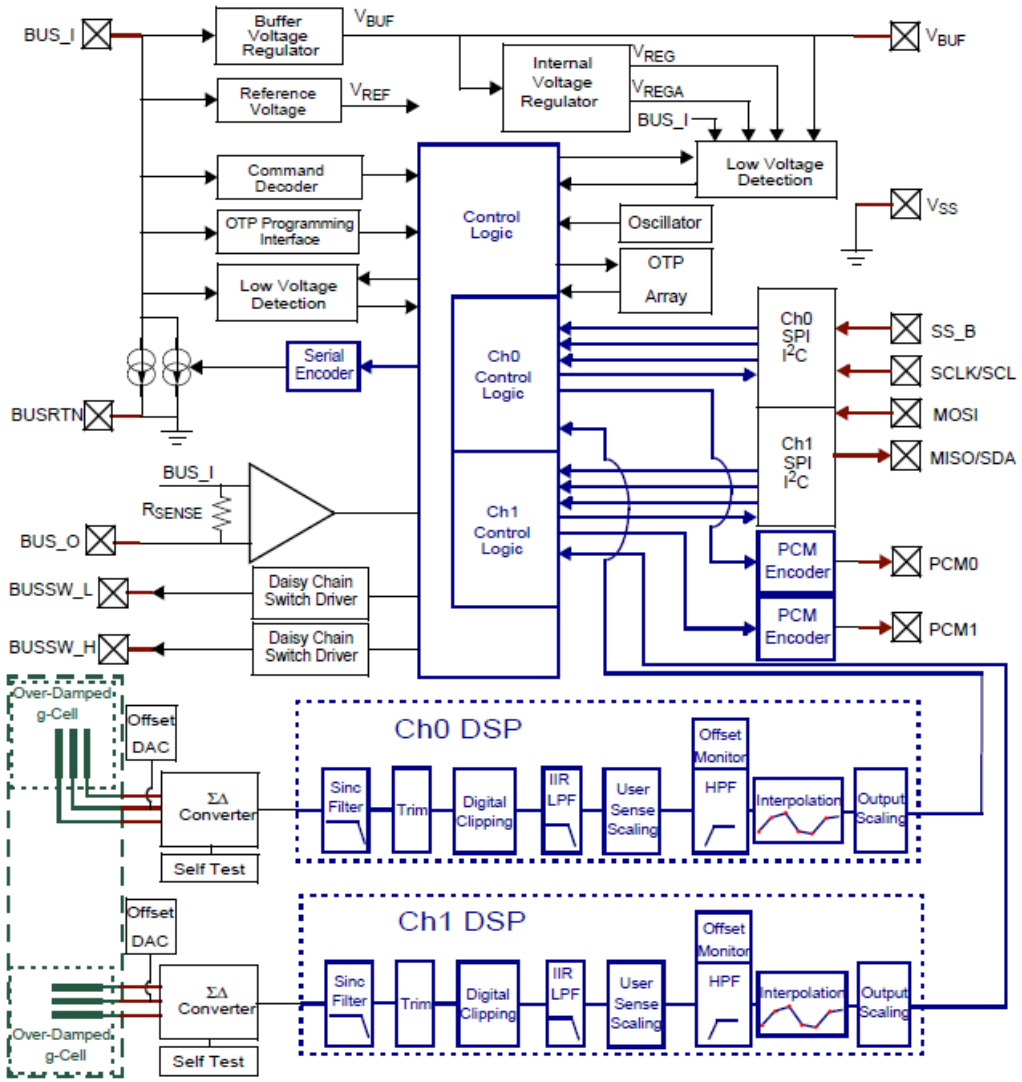
UMEMS	Single Axis			Dual Axis		
Gen 6	**X**	**Y**	**Z**	**XY**	**XZ**	**YZ**
Low g	●		●	●	●	
1.5g to 20g	L		L	LL	LL	
Medium g	●		●	●	●	
15g to 150g	M		M	MM	MM	
					ML	
High g	●	●	●	●	●	●
50g to 500g	H	H	H	HH	HH	HH

L: Low; M: Medium; H: High





Dual Channel Inertial Sensors



Features

ASIC

- 180 nm CMOS
- Maximum operating voltage: -0.3V - 20V
- Digital Signal Processing
- DSI3 Compatible
- PSI5 V2.1 Compatible, AKLV27 Compatible, Airbag Substandard
- HVST, IDDQ, Analog IDDQ, Scan, Logic BIST

Transducer

- 2 Independent transducers in a common cavity
- X-Axis and Z-Axis UMEMS (Unique Range for each Channel)
- Bidirectional Self Test, Independently Controlled for each Channel

Operating temperature

- -40C to 125C

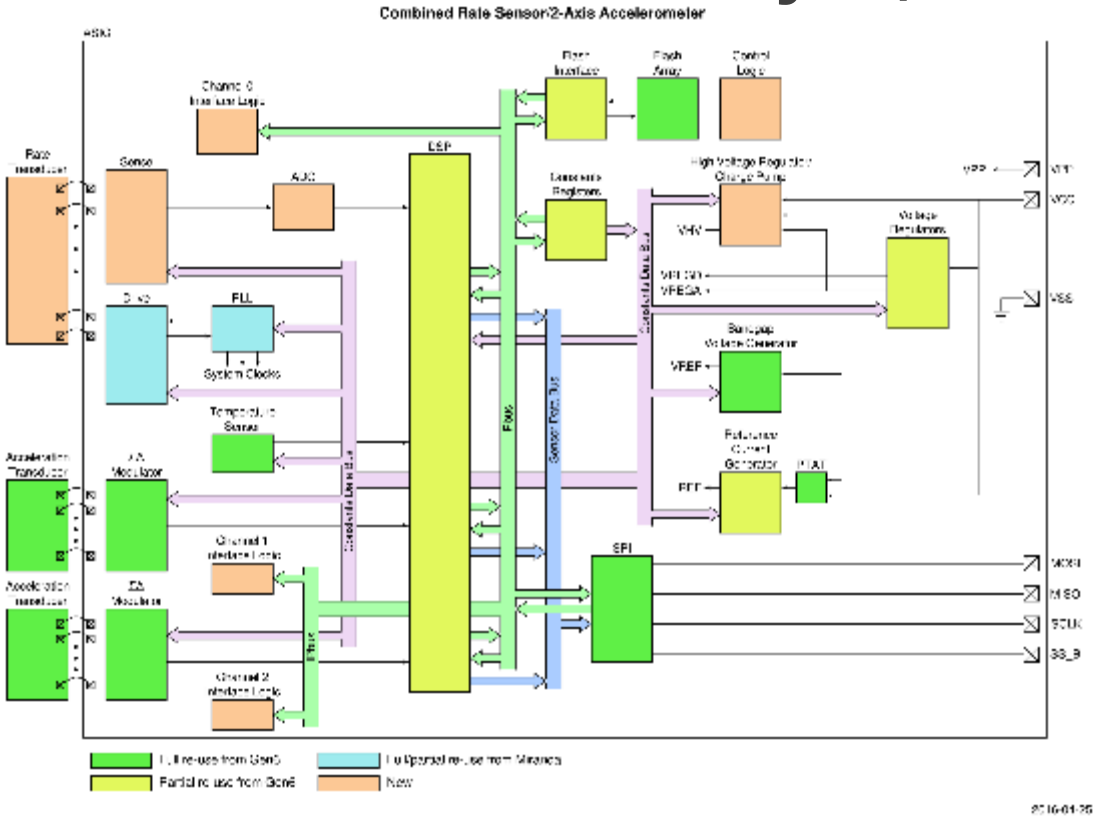
Package

- 16 pin QFN 4 mm x 4 mm x 1.45 mm
- Inspectable Solder Joints

AUTO COMBO GYRO

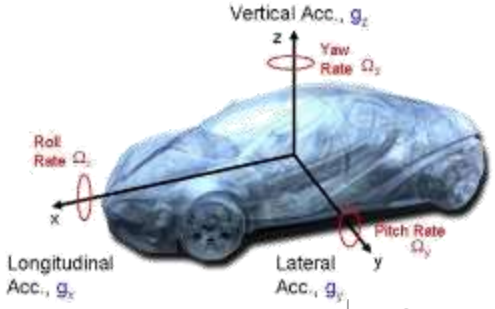
Acadia: SPI Based Gyro, Inertial Sensor Combo - ΩZ Gyro, XY Low g (FXCS10113AEPR2)

- **Transducer / Sensor**
  - Gyro: Decoupled tuning fork design based on Coriolis
    - Ω_Z rate sensor +/- 125 º/s, 262 LSB/º/s
    - Common mode rejection structure
  - Low g: 2 Independent transducers in a common cavity
    - UMEMS™ XY: ± 1.5g to ±15g
- **ASIC / Signal Processing**
  - 180 nm CMOS, LL18UHV
  - Operating voltage: 3.3V or 5.0V
  - Temperature Range: -40C to 105C
  - Gyro processing (16-Bit Data)
    - Synchronous Demodulator for the Coriolis signal
    - Signal Compensation
    - Low Pass Filter selectable between 10Hz and 100Hz, 3-Pole
  - Low g Accelerometer: Digital Signal Processing (12-Bit Data)
    - C2V, Sigma Delta Modulator and Sinc Filter
    - Signal Compensation
    - Low Pass Filter options from 10Hz to 100Hz, up to 3-pole
    - Optional 0.04Hz Offset Cancellation High Pass Filter with selectable output rate limiting
  - 32-Bit SPI
    - 11 MHz maximum SPI Clock frequency
    - Error Detection via 8-Bit CRC, Message Counter and Source Identification
- **Package**
  - QFN FAM 6x6



Target Application

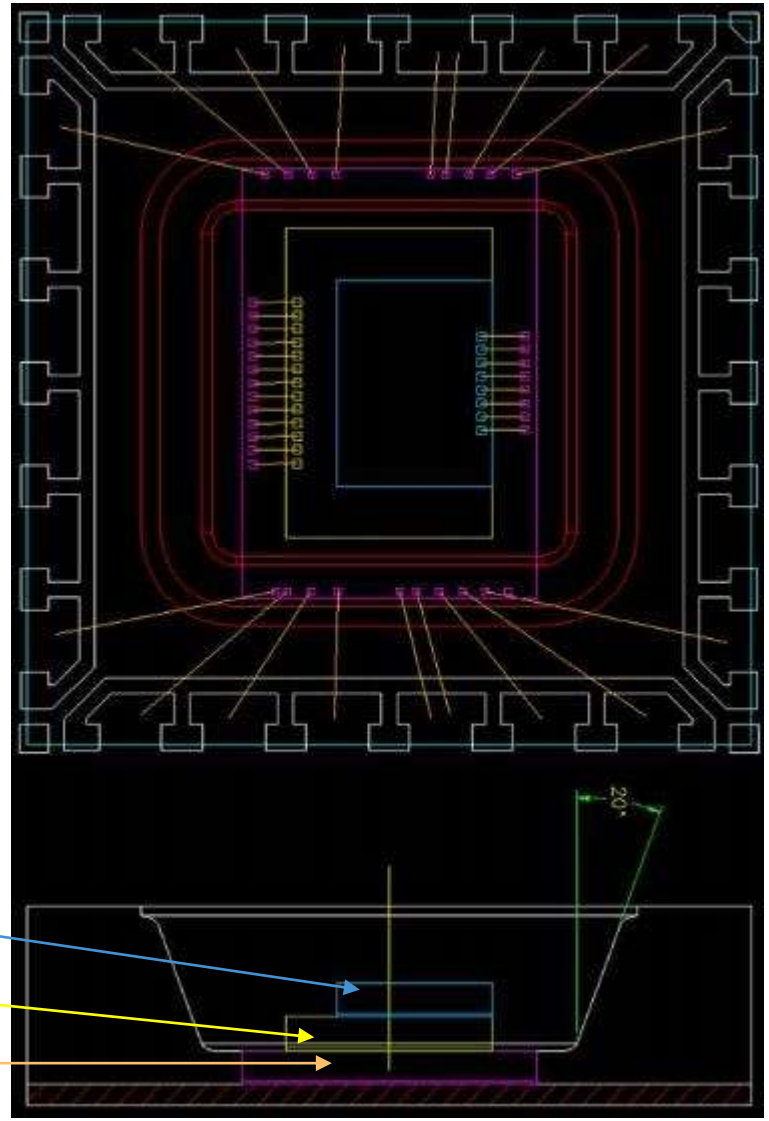
- Electronic Stability Control



Acadia: ΩZ Gyro, XY Low g, SPI based (FXCS10113AEPR2)

Package – QFN6x6- FAM

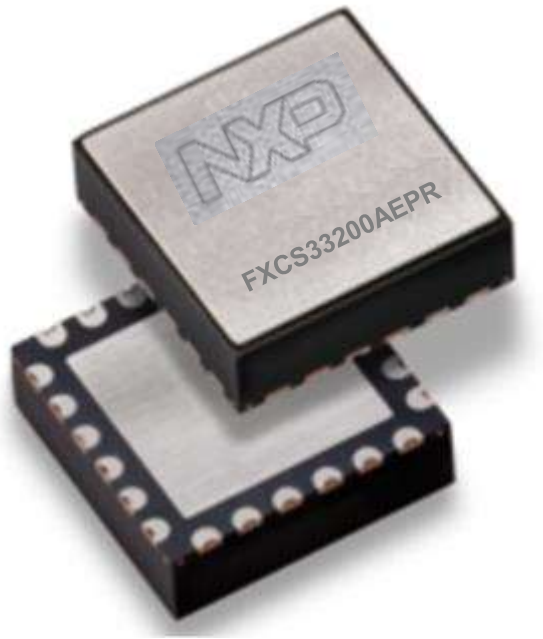
3 die stack MEMS in FAM cavity



Low-g

Gyro

ASIC

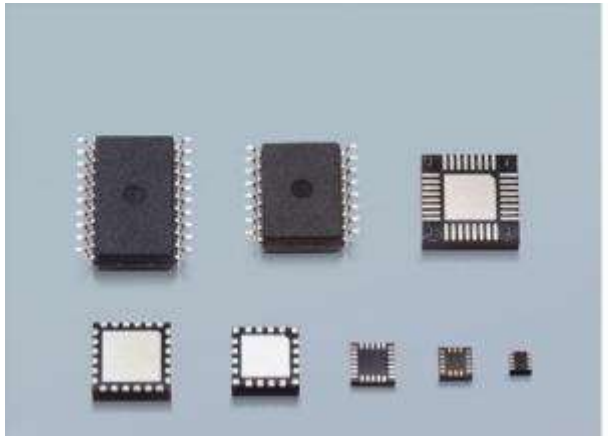


24-pins QFN 6x6
Film Assist Molding Technology
Wettable flanks

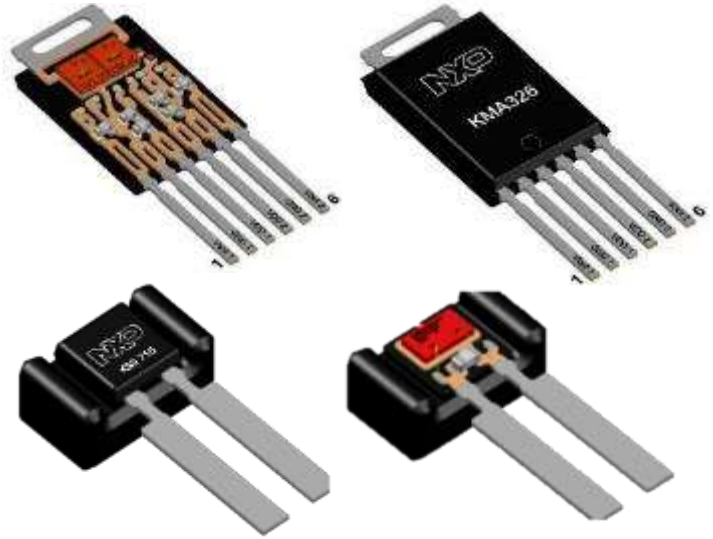
PACKAGING AND ECOSYSTEMS

Sensors Packaging Capability

Motion and Pressure Package Examples



Magnetic Package Examples



Products	Package
Airbag accelerometer Gen 4.2	QFN 6x6
Airbag accelerometer Gen 6 PSAT, dBAP and TPMS gen 5	QFN 4x4 QFN FAM 4x4
Automotive Gyro & Combo	QFN 6x6 (FAM)
Airbag Gen 7	TBD
TPMS Gen 4	QFN FAM 7x7
Consumer Pressure	LGA 3x5
Differential Pressure	LGA 4x5
Magnetic KMI7xx	SIL
Magnetic KMA3xx	SIL
Magnetic OH54x	SIL

Gen 4 and Gen 6 EcoSystem

DSI, PSI, SPI, and I2C airbag system

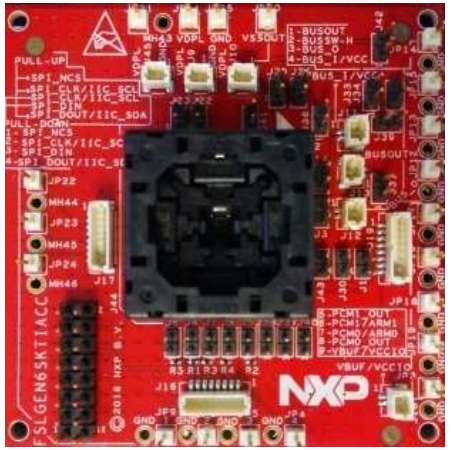
- Airbag hardware evaluation platform
- Software for evaluation

Complete technical documentation available to ease design

- Datasheets
- Application notes
- Reference design manual
- Official PPAP reports

Easy to use tools: Support design wins

- SafeAssure, functional Safety Program
- Technical training and hands on training on demand
- Fact sheet
- FAQ and other technical marketing presentations



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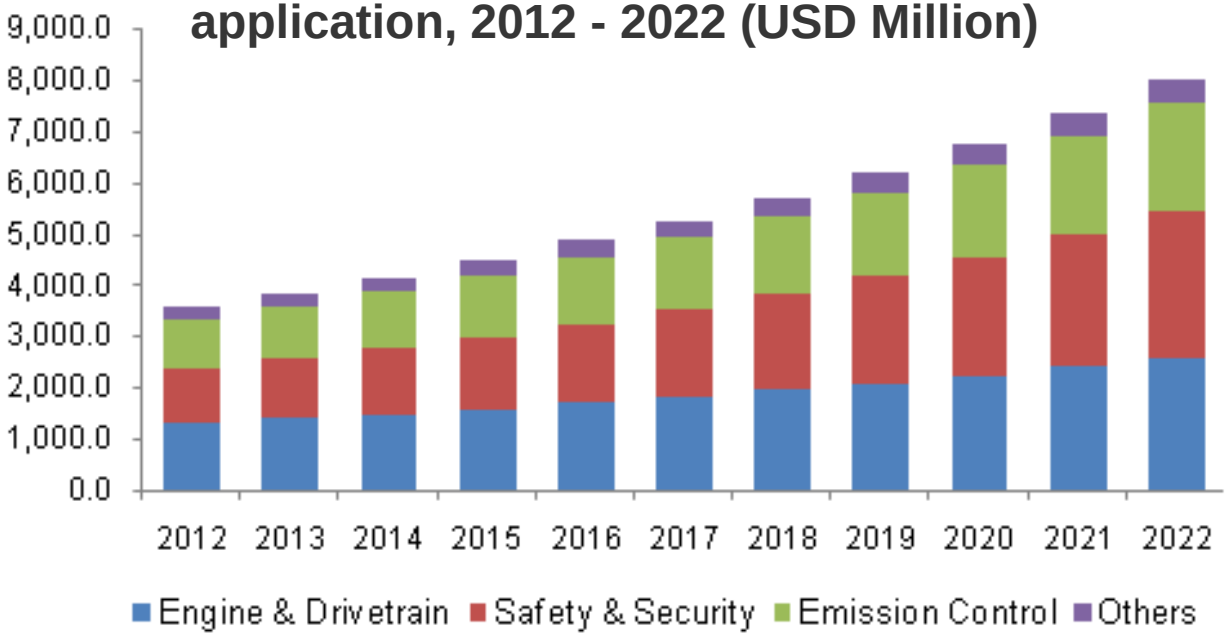
Pressure Sensors

Automotive Market continues to grow…

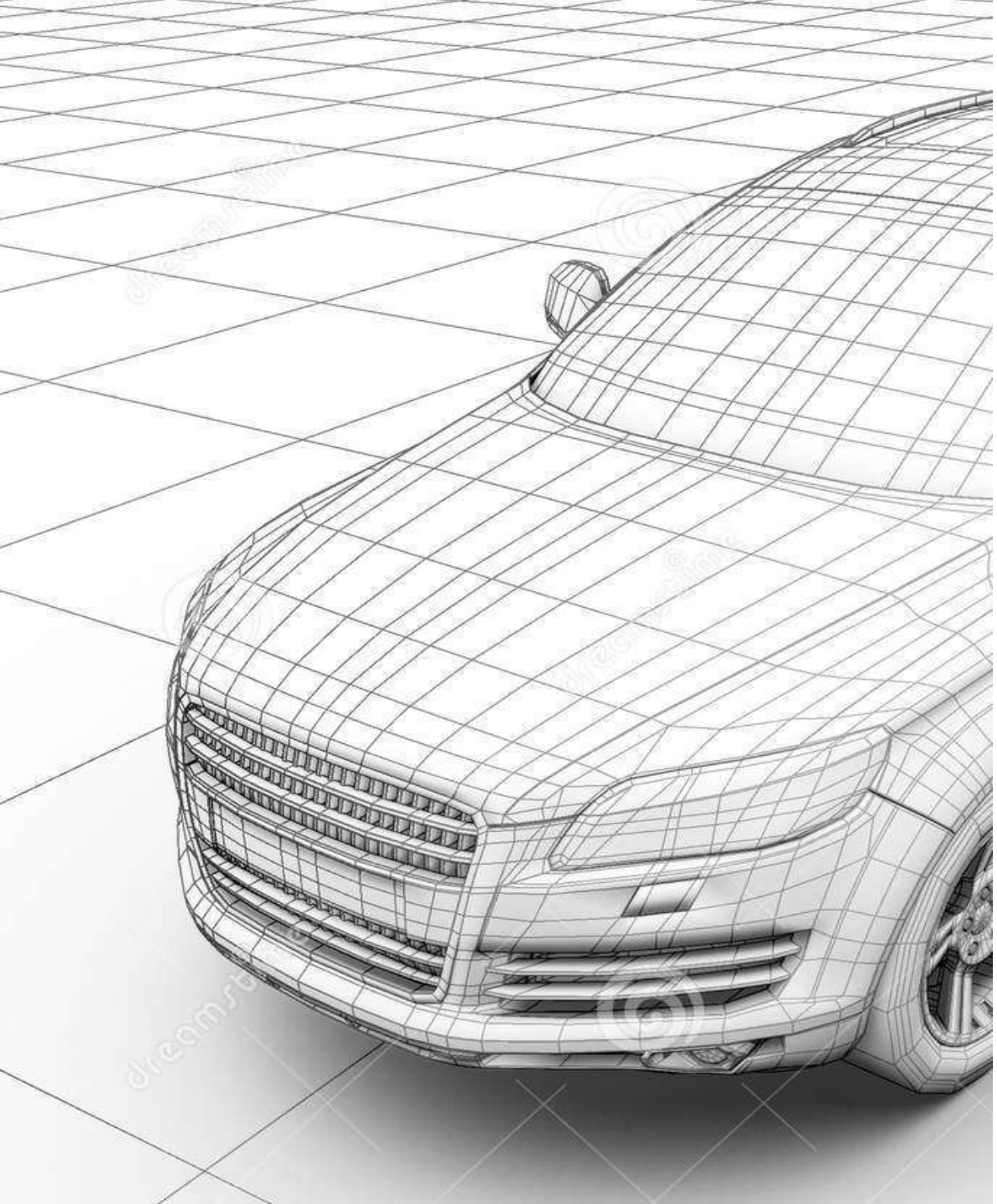
- **Safety First,** driven by consumers and regulatory organizations. Higher number of sensors in cars resulting in more information on safety, comfort and security.
- **Fuel Efficiency** regulations were tightened in 2009 and continue to drive changes in the industry.
- **Alternative Fuels** continue to have a strong presence. LPG is the leading alternative fuel in Europe for passenger cars.
- **Regional Growth,** Asia Pacific automotive sensor market was the largest regional segment and is expected to grow at a CAGR of 9.9% from 2015 to 2022

North America automotive sensor revenue by application, 2012 - 2022 (USD Million)



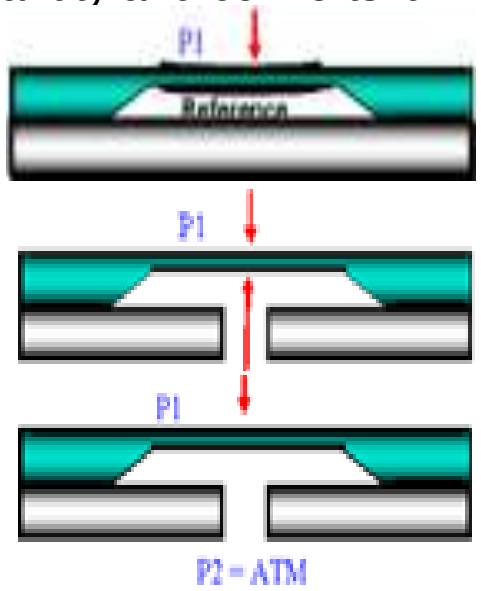
Source: Grand View Research

Safety applications to grow at a CAGR of 10.4% from 2015 to 2022.



Pressure Sensors

- A pressure sensor is a device that detects an absolute value or a change in a physical quantity and converts it into a useful input signal.
  - Absolute pressure
  - Differential pressure
  - Gauge pressure
- Automotive Applications
  - Engine Management
  - Safety
  - Emission control
  - LPG/CNG systems
- Medical/Industrial Applications
  - Air conditioning
  - Blood pressure monitor
  - Breathing machines
  - Inhalers
  - Water level monitor



Pressure Sensor Portfolio

A – Absolute
D – Differential
G – Gauge
V – Vacuum

MPX10/12/53 D G
10...53 kPa
SOP, Unibody

Uncompensated
High sensitivity analog output
Need external circuit for compensation and amplification

MPX2 Series A D G V
10...300 kPa
ChipPak, Unibody

Temperature Compensated
Integrated temperature compensation
Need external circuit for amplification

MPX7 Series D G
±2...±25 kPa
SOP

Integrated Pressure Sensor
Integrated signal conditioning for temperature compensation, linearization and amplification

MPX4 Series A D G
6...250 kPa
SOP, SSOP, Unibody

MPX5 Series A D G V
4...1'000 kPa
SOP, SSOP, Unibody

MPX6 Series A
100...400 kPa
SOP, SSOP

Package Examples

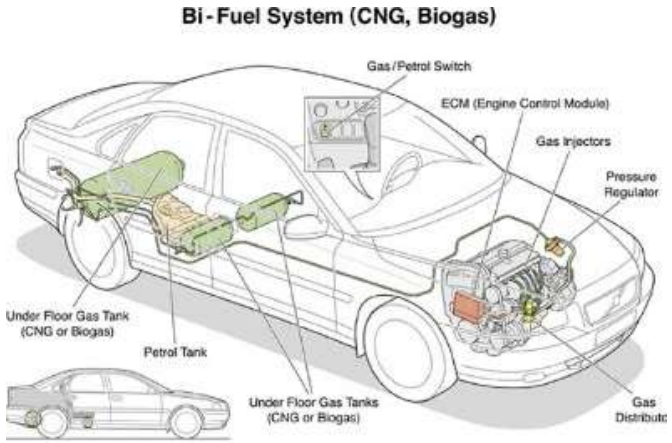
SOP Basic Case	SOP Side Port	SOP Axial Port	Unibody Dual Port	SSOP Basic Case	Medical ChipPak Case	LGA 3 x 5 mm Case

MPL3115 (Digital I²C) A
115 kPa Smart Baro/Pressure
3 x 5 mm LGA

Integrated Digital Pressure Sensor
I2C Digital Interface with digitized output in Pascals or meters.

NXP Pressure Sensors in automotive

Alternate Fuel

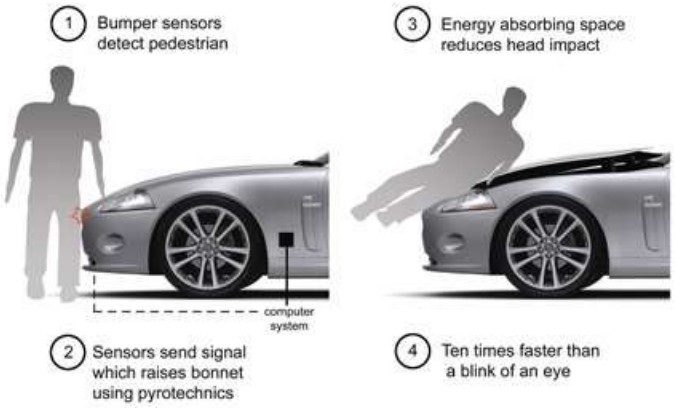


Manifold and Barometric Air pressure

Passenger detection

Side crash detection

Pedestrian Protection

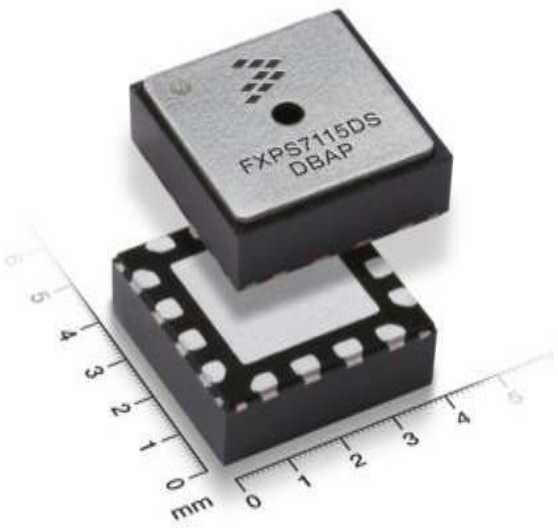


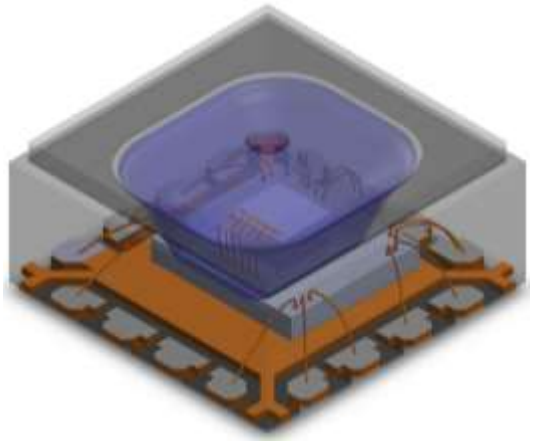
Comfort seating

Next Generation Pressure Sensor Platform

- **PSAT –** Pressure Sensor Satellite
  - Airbag Satellite sensor, Multi protocol

- **DBAP/AMAP** – Digital or Analog output
  - Engine Management BAP application
  - Engine Management MAP application
  - Engine Management Turbo application
  - Engine Management LPG applications
  - Comfort seating
  - Vacuum Brake booster





Sample now
SOP Q1 2018 for PSAT
SOP Q2 2018 for DBAP/AMAP

PSAT: DSI3 & PSI5 Satellite Absolute & Relative Pressure Sensor

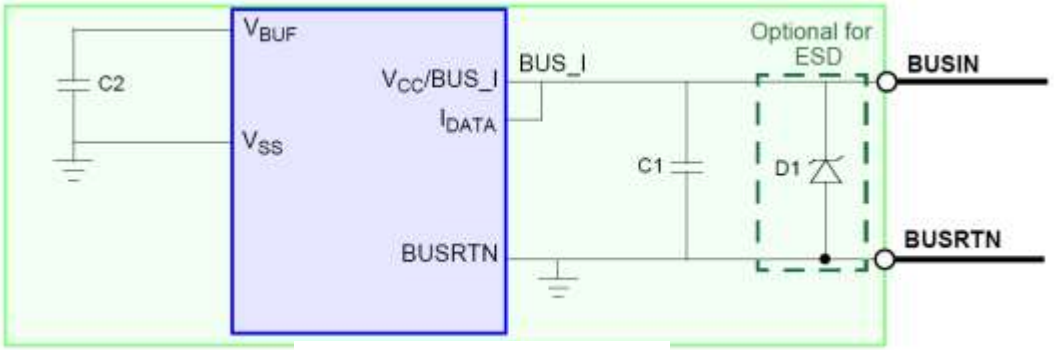
Product Features

- **DSI3 Compatible**
- AKLV29 V1.3 Compatible, **PSI5 V2.1 Compatible**
- **Redundant P-Cells with Mismatch and common Mode Error Detection**
- Discovery Protocol for physical location identification
- Analog output for monitoring of the absolute pressure signal
- **Smallest size QFN 4x4x2.0 mm packaging** (27% of competitor PSAT footprint)
- High Speed Programming Mode via DSI3 for programming of either DSI3 or PSI5 satellites
- **ISO26262** design and support circuitry for IS026262 compliance

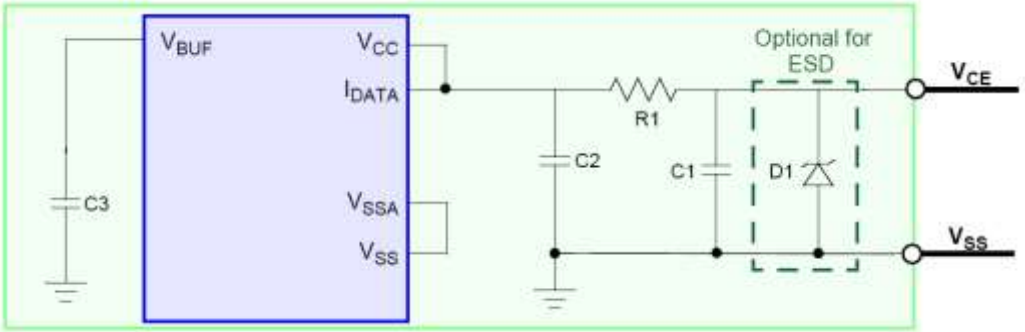
Parametrics

- 40kPa - 140kPa Absolute Pressure Range
- -40°C to 125°C Operating Temperature Range
- ASIC technology: 180 nm CMOS, LL18UHV
- Digital Signal Processing

DSI3 Application Diagram



PSI5 Application Diagram



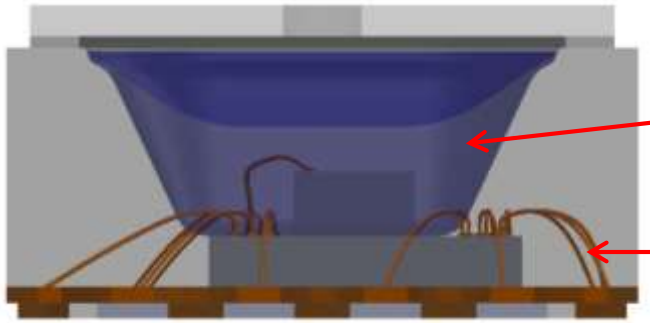
dBAP / aMAP: Barometric pressure sensor family

Features

- Multiple pressure ranges (115kPa, 250kPa, 550kPa, 1500 kPa, custom)
- Multi interface: SPI, I2C, Analog
- **Redundant Pressure Transducers enable embedded self test**
- 1 Mhz Sigma Delta ADC up to 16 bit
- 8 bit ADC for temp sensor
- Digital self test for digital signal chain verification
- Interrupt capabilities
- Unique serial number in OTP register + additional traceability information
- Open OTP registers for user data (30 bytes)
- Reference design for porting on PCB.

Package Technology

- QFN Film Assisted Mold Technology
- Air vent in 4x4 QFN package stainless steel lid = 0.5mm diameter.
- **Small hole prevents large insect intrusion**



Protective gel fully encapsulates interchip wirebonds and protects from environment

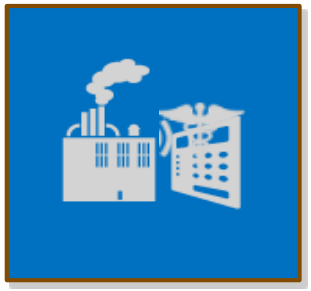
Wirebonds to leadframe are fully encapsulated in mold compound

Competitor Part vs. NXP Part

Non-Automotive Pressure Sensor Applications

Industrial

- HVAC
- Gas metering
- Water metering
- Water Heaters
- Leak detection for gas & water media
- Water level detection
- Beverage dispensing



Commercial

- Washing machines
- Dishwashers
- Small appliances
- Smart watches
- Bike computers
- Fitness trackers

Medical

- Inhalers
- CPAP mask and machines
- Activity monitors
- Blood Pressure Monitoring
- Liquid level detection
- Surgical equipment
- Negative pressure wound management

TIRE PRESSURE MONITORING

TPMS Implementation In Light or 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

BL Sensors: Tire Pressure Monitor Sensor

Driving Innovation in TPMS Sensors

GEN5
FAM
QFN

GEN4
FAM
QFN

GEN 5
500, 900, 1500kPa
2-Poly Pcell, UMEMS Gcell 16 bit
MCU (140nm)
4x4x1.98mm FAM QFN

Streaming Sensor
BLE Demo

FXTH88 architecture is similar to FXTH87
→ High % firmware and software re-use
→ Simple transition

FXTH88
500, 900, 1500kPa
2-Poly Pcell, UMEMS
Gcell
4x4x1.98mm FAM QFN

1/3 the size of previous generation
+10% battery life improvement

+30%
battery life improvement

FXTH87
450,900,1500kPa
Z & XZ Axis
0.25um TSMC, 2-poly
7x7 FAM QFN

FXTH87E
500,900 kPa
Z & XZ Axis
0.25um, 2-poly
7x7 FAM QFN

PPAP SEP2017

Proposal
Planning
Execution
Production

Left Edge :
First Sample Date
Right Edge :
Product Qualification

In Production | **2016** | **2017** | **2018** | **2019** | **2020**

FXTH87 vs. FXTH87E vs. FXTH88

Increased Performance – Reduced Power Consumption

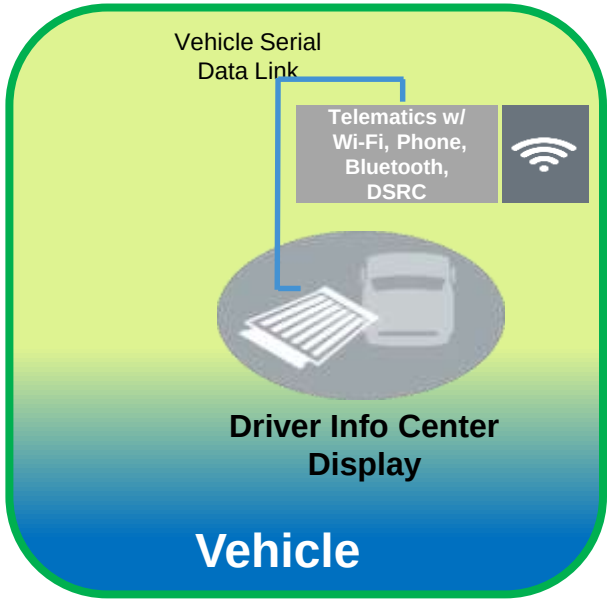
	FXTH87	FXTH87E	FXTH88 Targets
Smaller Package	7 x 7 x 2.2mm QFN FAM		4 x 4 x 1.98mm QFN FAM
Silicon To Enable more Features	8-bit MCU, 2-poly G-cell, 2-poly P-cell		8-bit MCU, UMEMS G-cell, 2-poly P-cell
	Memory: 16kB flash (8kB User, 8kB NXP) 512B RAM, 64B Registers		
Lower Power Consumption	Stop @ 25ºC 3V: 500nA typ, 700nA max	Stop @ 25ºC 3V: 200nA typ, 350nA max	
	4MHz Run: 2.5mA typ, 2.9mA max	4MHz Run: 2.1mA typ, 2.5mA max	
	5dBm 434MHz 9.6kb/s: 7.6mA		5dBm 434MHz 38.4kb/s: 7.1mA
Transfer Functions	Offsets can overflow 9-bit data range	In-spec tolerances within 9-bit data range	
Improved Pressure Accuracy	0ºC to 70ºC 100 to 500 kPa: ±7 kPa 100 to 900 kPa: ±10 kPa	-40ºC to 85ºC 100 to 500 kPa: ±5 kPa 100 to 900 kPa: ±5 kPa	
More Algorithms, Functions	User provides software	NXP provided software: 1. Quadrant Detection 2. Angle Detection 3. Rotation Direction & Per. Det.	NXP provided software: 1. Infinite Impulse Response Filter 2. Cap-mount & tire-mount Auto-localization
High Sampling Rates	~285Hz max	~400Hz max	

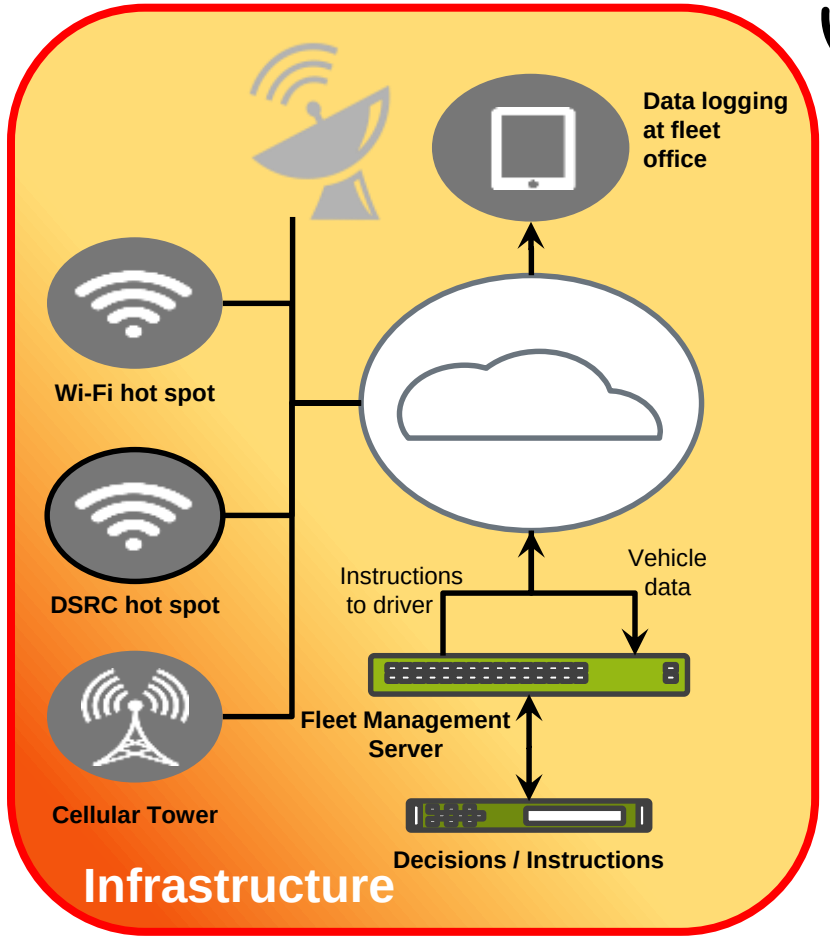
TPMS + BLE

BLE Enables Tire Management Data Analytics

Streaming Sensors Enable Intelligent Tires

- Smartphone App's:
  - Pressure, Temperature
  - Service Reminders
  - Predicted Useful Life, etc.





BLE Tire Pressure Monitor Sensor – EVBs

NXP Is Sampling BLE TPMS Sensors

Kinetis
32bit ARM+BLE

+

Nogaro TPMS
FXTH87E EVB

Available BLE TPMS EVBs

TPMS MODULE+2.4GHz
Valve Stem Mount
Rectangular form factor

TPMS MODULE+2.4GHz
Tire Mount
Circular form factor

03.

Magnetic Sensors

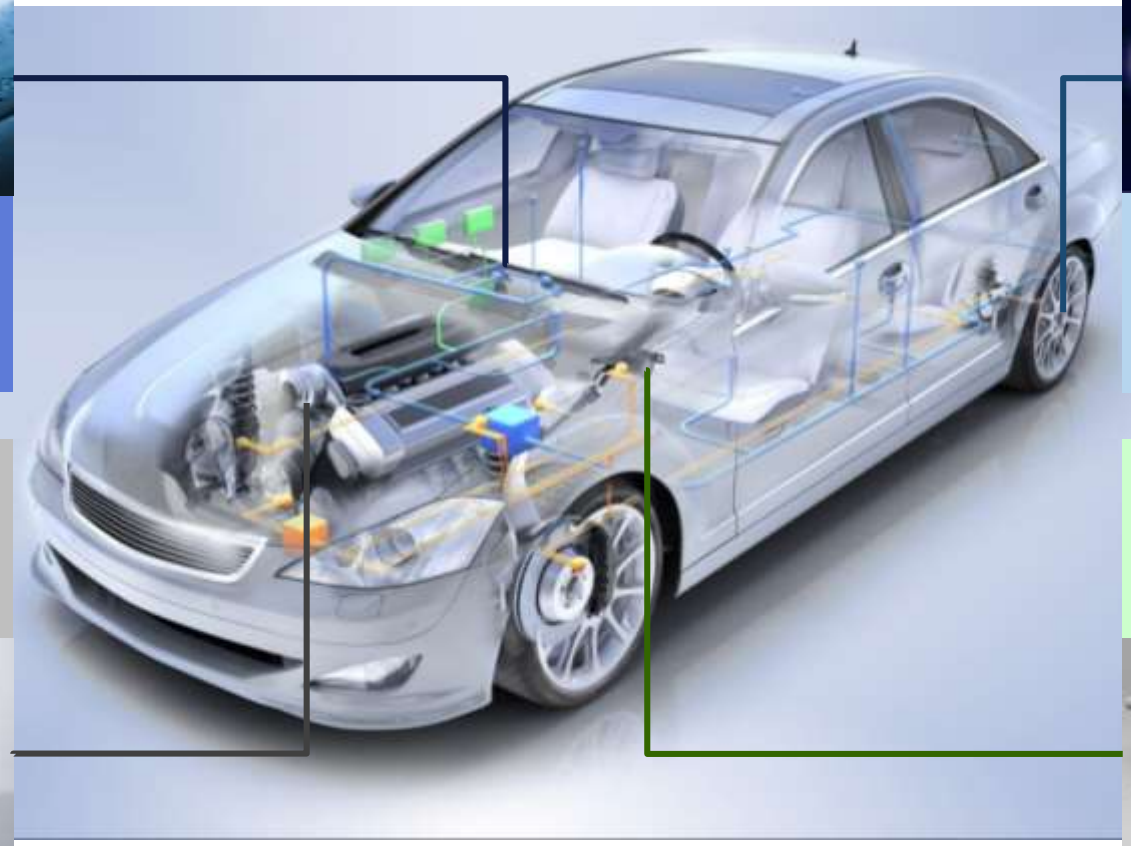
Automotive Application Domains of NXP Magnetic Sensors

More than 1.5Bpcs AMR sensors by NXP in field.
Robust, reliable over temperature, functional safety.

Wiper Control

2x KMZ49

Angular magnetic field sensor
with two galvanic separated Wheatstone bridges, sine & cosine V-output



Braking

4x KMI83

Rotational wheel speed sensor
for active & passive ABS encoders with current pulse & digital protocol output.

Dual-channel programmable
angular sensor with int. capacitors for
Electric Throttle Control (ETC) &
Exhaust Gas Recirculation (EGR)

1x KMA320

Engine Control

Angular magnetic field sensor
with integrated signal amplifier
for Steering Angle Sensing (SAS)
& BLDC motor commutation

3x KMZ60

Steering

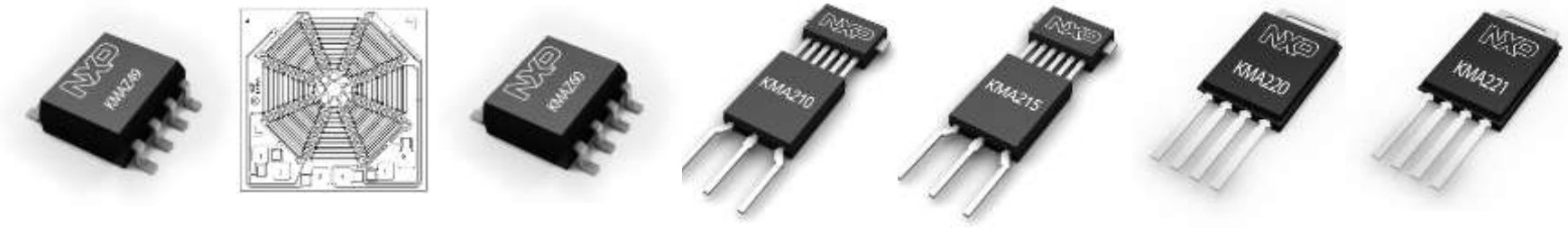
New sensor technology under implementation.
First TMR products planned in 2020.

AMR: Anisotropic Magento-Resistive
TMR: Tunnel Magento-Resistive

Product segment

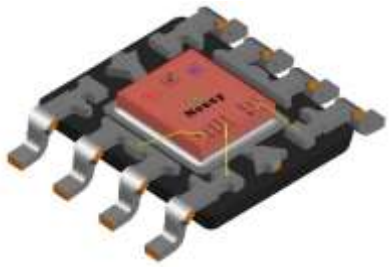
Angular sensors

Magnetic field sensors		Sensor + integrated amplifier	Programmable sensors			
KMZ49/41 sin/cos	**X3T/G-OH047/048** sin/cos	**KMZ60** amplified sin/cos	**KMA210** 1x analog	**KMA215** 1x SENT	**KMA220** 2x analog	**KMA221** 1x analog

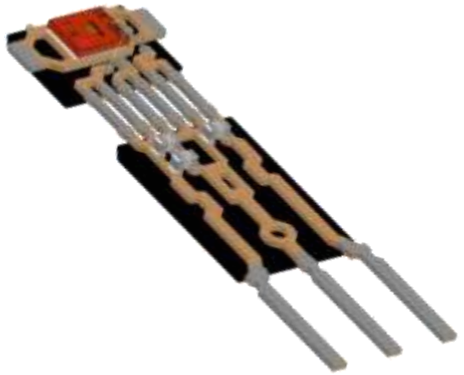


Next gen KMA angular sensors: KMA3xx/KMZ80 product family

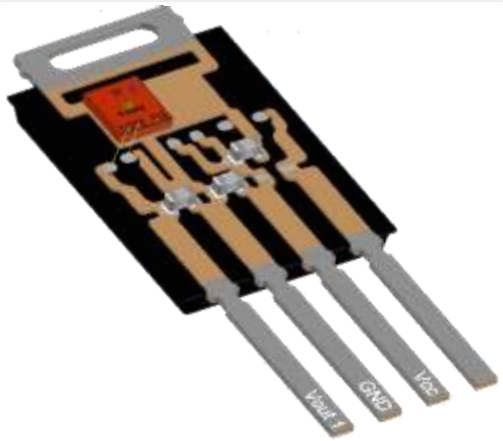
KMZ80



KMA310



KMA321



KMA320

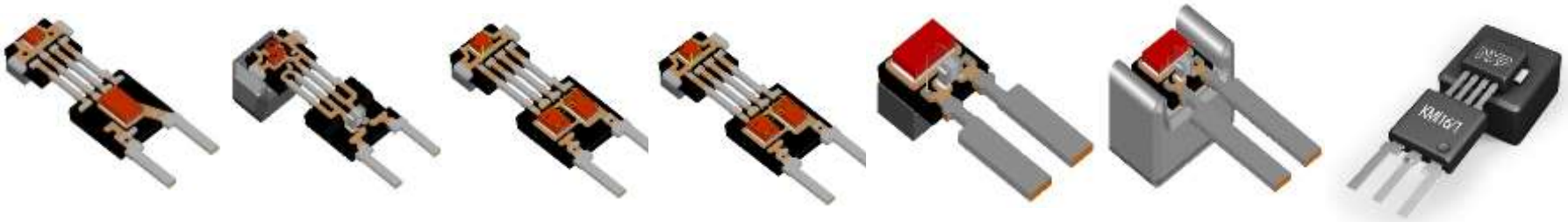
KMA326

Samples Available now
Production Q1, 2018

Product segment

Wheel speed sensors

Standard ABS sensors active/passive encoders			High-end ABS sensors active/passive encoders			Transmission passive encoder
KMI15 current output dual-chip	**KMI17/4** current output dual-chip	**KMI23** current output triple-chip	**KMI25** digital protocol triple-chip	new **KMI83/P** digital protocol single-chip under dev.	new **KMI84** current output single-chip under dev.	**KMI16/1** voltage output dual-chip



packages with magnets for active encoders

Sampling: Q3, 2017
Production 2021

04.

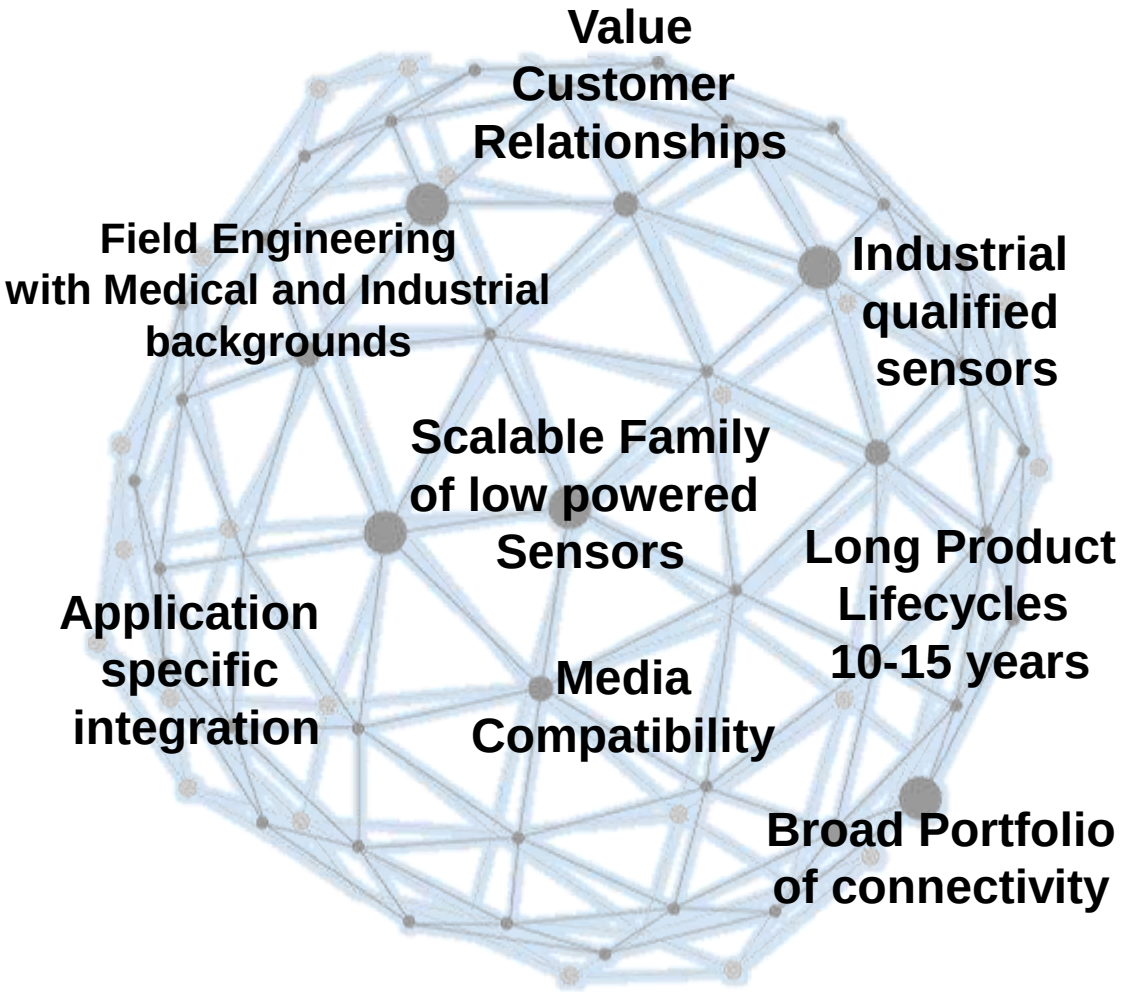
Conclusion

NXP Sensors

Delivering Trusted Sensor Information for a Secure and Connected World

NXP sensing solutions for trusted

- data accuracy & integrity
- functional reliability
- long term supply continuity



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05.

Q&A

SECURE CONNECTIONS
FOR A SMARTER WORLD