MEMS Sensors in Chassis and Active Safety Applications

Vehicle Dynamic Expo, Technology Forum, 18 June 2009

Matthieu Rezé, EMEA Automotive Sensors Marketing

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One Billion MEMS Milestone just passed...

One Billion and Counting

From 1980 to 2009 Freescale has designed, produced and shipped innovative sensor products to global customers

1980
We manufacture our first uncompensated pressure sensor

1982
Pressure sensors are supplied for manifold absolute pressure (MAP) to significantly reduce exhaust emissions and fuel consumption

1991
Bipolar integrated pressure sensor production begins

1992 to present
Dedicated supplier to the critical care medical market through shipment of over 60 million units for the invasive blood pressure market

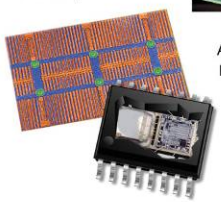
2002
Began providing pressure sensors for respiratory medical equipment

100 MILLION

1985
Sensor products release a temperature compensated pressure sensor

Late 1980s
Freescale* begins developing the first surface micromachined inertial sensors for the automotive airbag market

1996
Inertial sensors start volume production



Late 1990s
A new wingback/PDIP package is developed for the Z-axis inertial sensor

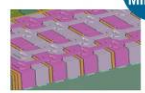
2003
The pressure sensor portfolio expands with the tire pressure monitoring system, utilizing capacitive technology to save power

200 MILLION

Early 2000s
Inertial sensor portfolio expands with X-, XY- and Z-axis low-g products for the consumer market

2003
Satellite accelerometers introduced for airbags provide smarter, faster response time deployment

May 2005
Freescale introduces its first 3-axis MMA7260Q low-g inertial sensor, alleviating the need for multiple devices



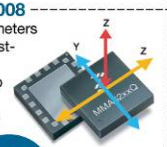
July 2006
First HARMEMS technology MMA62xxEG products are shipped for airbags with robust accuracy

June 2007
Spalding uses the ZSTAR wireless sensing triple axis reference design for an intelligent basketball that tracks trajectory

400 MILLION

November 2008
Synerject announces its ongoing use of Freescale pressure sensors for robust, cost-effective ECUs for two- and four-stroke engine management

December 2008
3-axis accelerometers offer reliable, cost-effective freefall detection to help protect data stored on laptop hard disks



800 MILLION

February 2008
Motion-sensing accelerometer enables interactivity of Guitar Hero® and other popular video games

2008
TPMS MPXY8300 highly integrated single-package low-power solution:

- Pressure sensor
- 8-bit MCU
- RF transmitter
- 2-axis X- and Z-axis accelerometer

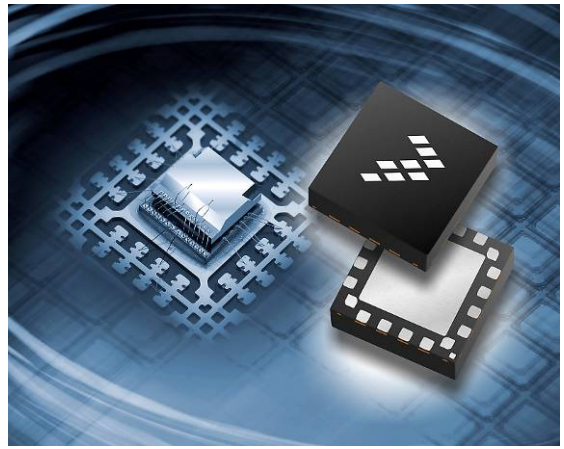
June 2009
MPL115A first digital barometric pressure sensor with easy-to-use digital interface, small package and low power

April 2009
MMA7660 intelligent 3-axis digital accelerometer introduced for advanced mobile phone interfaces

*The Semiconductor Products Sector of Motorola, Inc. became Freescale Semiconductor, Inc. in 2004.

Content

- Automotive Safety Market Trends
- Freescale Technology Capabilities
- MEMS content in Suspension and VDC Applications



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Automotive Electronic System Trends Are not Changing

Going Green

Stringent environmental regulation around the world

- EU target to reduce **CO2 emission** maintained
- Emerging market to adopt European emission standards
- **New US administration** enforcing new stringent rule
- Oil prices will **go up again**

Safety

Stringent safety regulation around the world

- **ESP & TPMS** mandated in the US (2012 / 2007)
- **ESP & TPMS** to be mandated in Europe (2012)
- **TPMS** to be mandated in China
- New **NCAP** rating to include active safety equipment

Regulation Driven

Connectivity/ Infotainment

The need to stay connected

- **Consumer electronic** penetrating the car
- **Wireless** inside and out
- eCall functionnality may become mandatory

The Affordable Vehicle

Car prices in the current economic situation !

- 30 million cars in emerging markets
- Changing **purchasing priorities** in developed market
- **Low cost does not mean low electronic content**

Consumer demand

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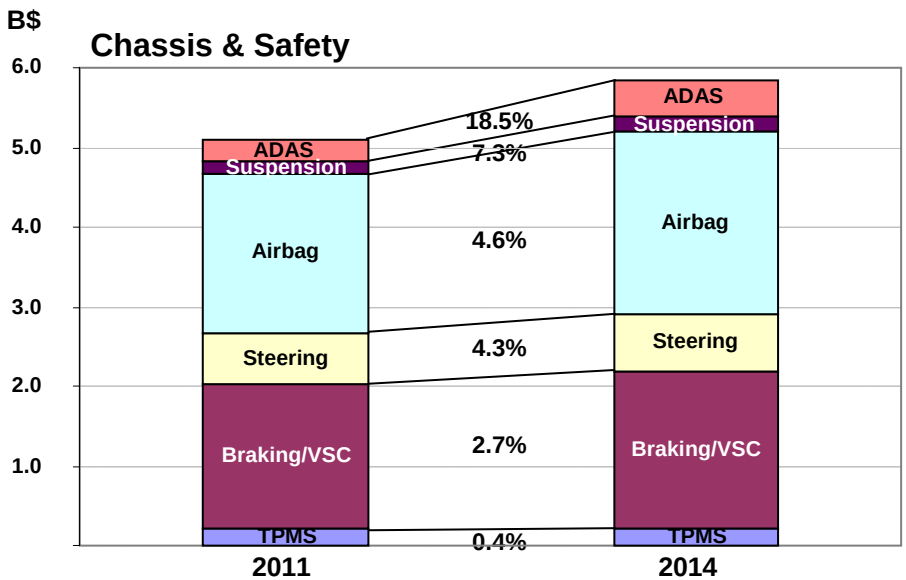
Automotive Electronic System Trends: Safety

Safety

More than
1.2 Million people
are killed on the world's roads every year !

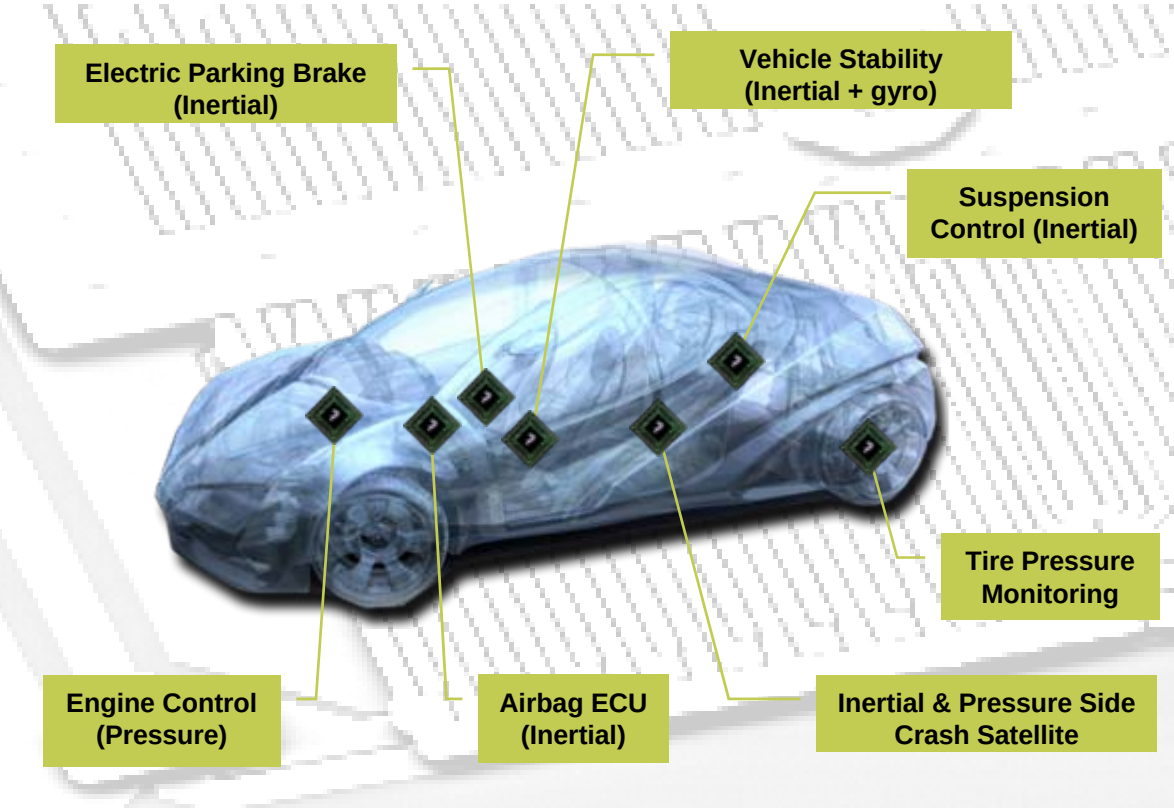


Source: Strategy Analytics

- **ESP** mandated in the US and in Europe
- New **NCAP** rating to include active safety equipment
- Active suspension being implemented in series by 2012 at some car OEMs in Europe

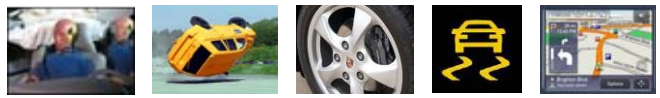
- MEMS sensors are the enablers
  - ESP: Inertial and Yaw rate sensors
  - Suspension: Low g sensors

Freescale commitment to Automotive and MEMS



Market Leader

- FSL is ranked #3 in the Automotive MEMS Sensors market
- Broad Standard portfolio



Business Facts

- Shipped **1 billion** Sensors, since 1980
- Since 1997, **450 million units acceleration sensors** shipped in custom safety automotive applications
- Among the largest supplier of **barometric pressure sensors for engine management**

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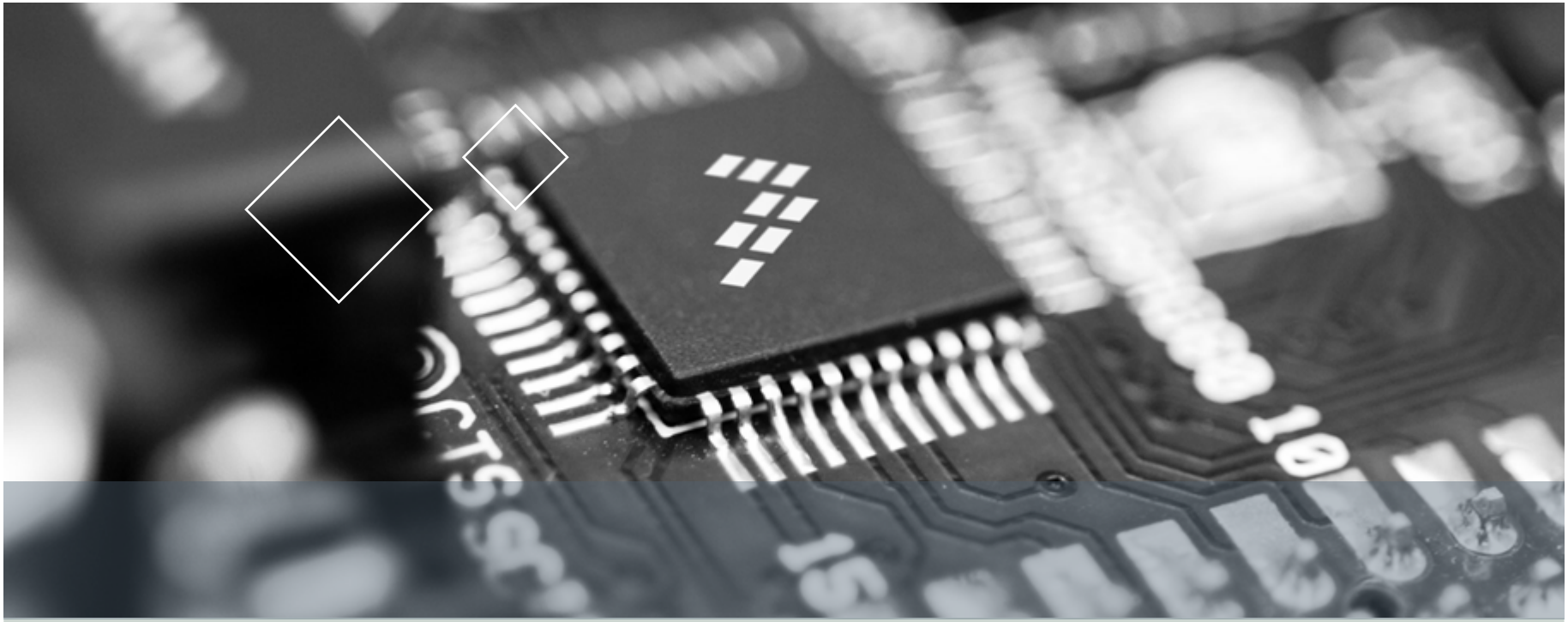

Technology and Packaging

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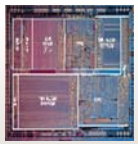
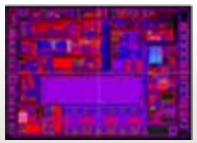
Freescale Integration Capability

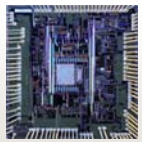
Proven IP Portfolio: SoC



Embedded Control/Memory



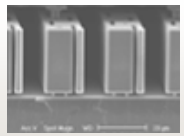
Hi-Performance Analog



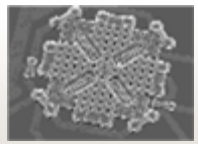
Power Management

Connectivity

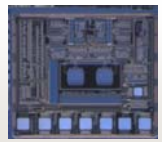
Diverse MEMS Sensing Technologies



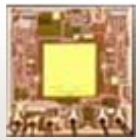
High Aspect Ratio



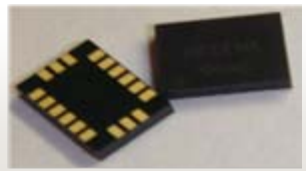
Surface Poly



CMOS Surface Poly



Integrated Bulk



Flexibility in Proven ASSP/ASIC and SiP/SoC Techniques Enables Fast and Low Risk Time to Market

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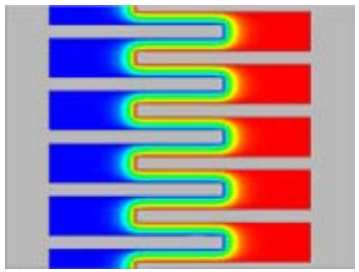
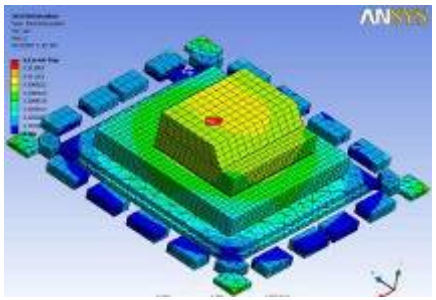
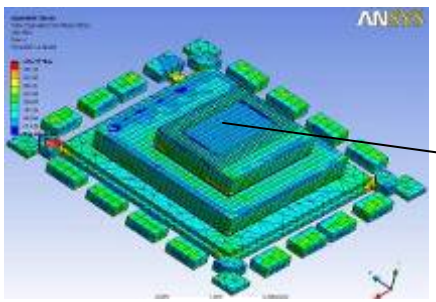
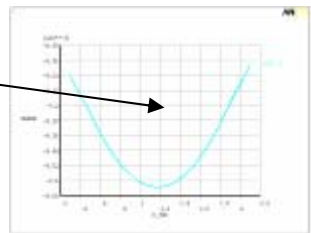
Simulation and Modeling Capabilities









- Use FEA to respond to the “Multiphysics” challenge of MEMS design: Mechanics, Electrostatics and Fluidics.
- Use analysis to study TCO (Temp Coefficient Offset) behavior in various package.
- Use analysis to study vertical and lateral deformation of the g-cell
- Model package deformations over temperature and extract surface curvature where transducer sits.

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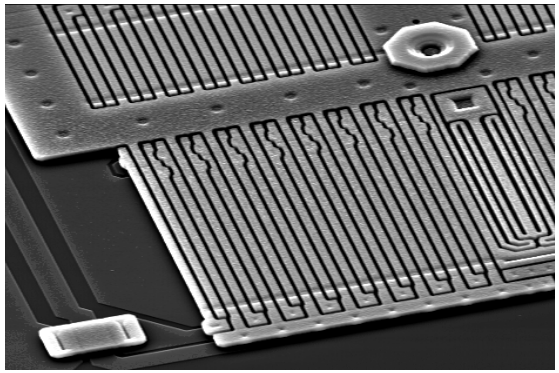
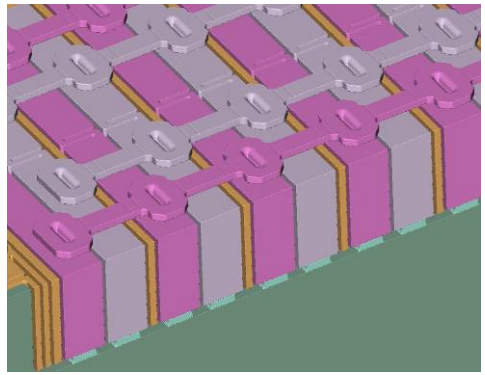
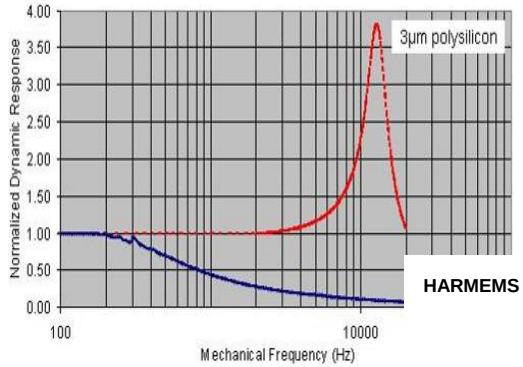
Various X-axis Transducers



Poly-Si lateral transducer
(3 um poly-Si mechanical layer)



HARMEMS cross section
(20 um single crystal-Si mechanical layer)



- **Designed to cover 1g to 200g**
- **Underdamped mechanical response**
- **No squeeze film damping**

- **Designed to cover 1g up to 500g ranges.**
- **Over-damped performance (Squeeze film damping)**
- **Symmetric layout for parasitics match**
- **Improvement in Temperature Coefficient Offset (TCO)**
- **Better sensitivity and nonlinearity**
- **Improvement in vertical stiction**

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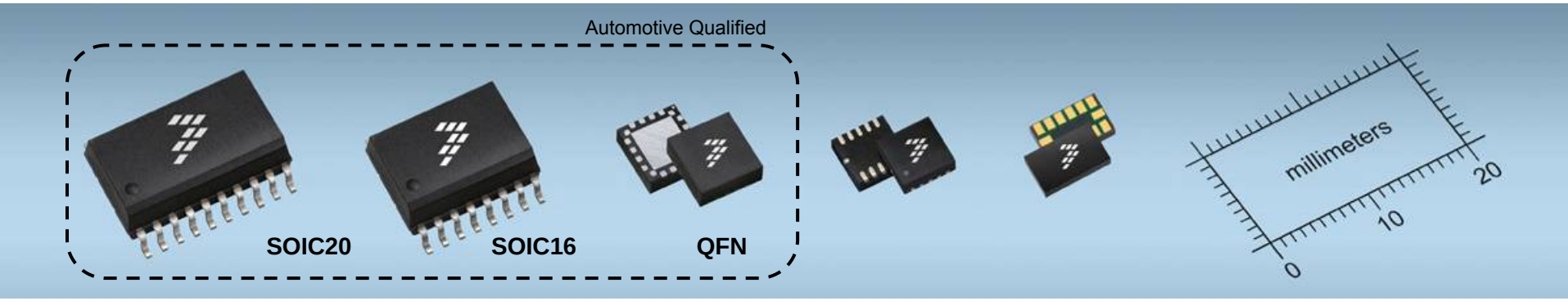
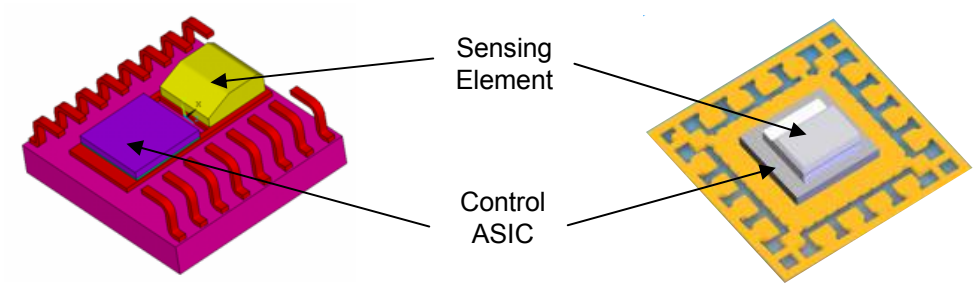
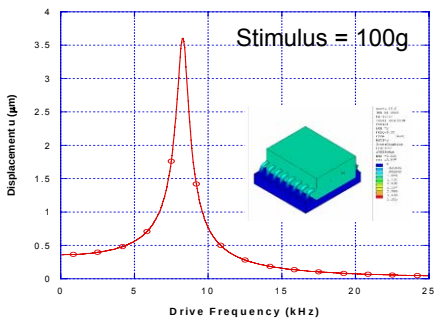
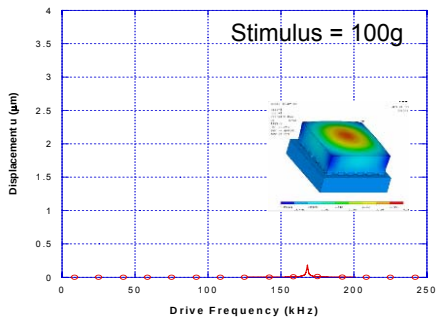
Freescale Inertial Sensors Packaging





- 2 Resonance Modes, X & Y both at 8.3 kHz
- **Resonance in the band of interest for car vibration**





- First resonance mode at 168 KHz
- **Resonance out of the band of interest for car vibration**

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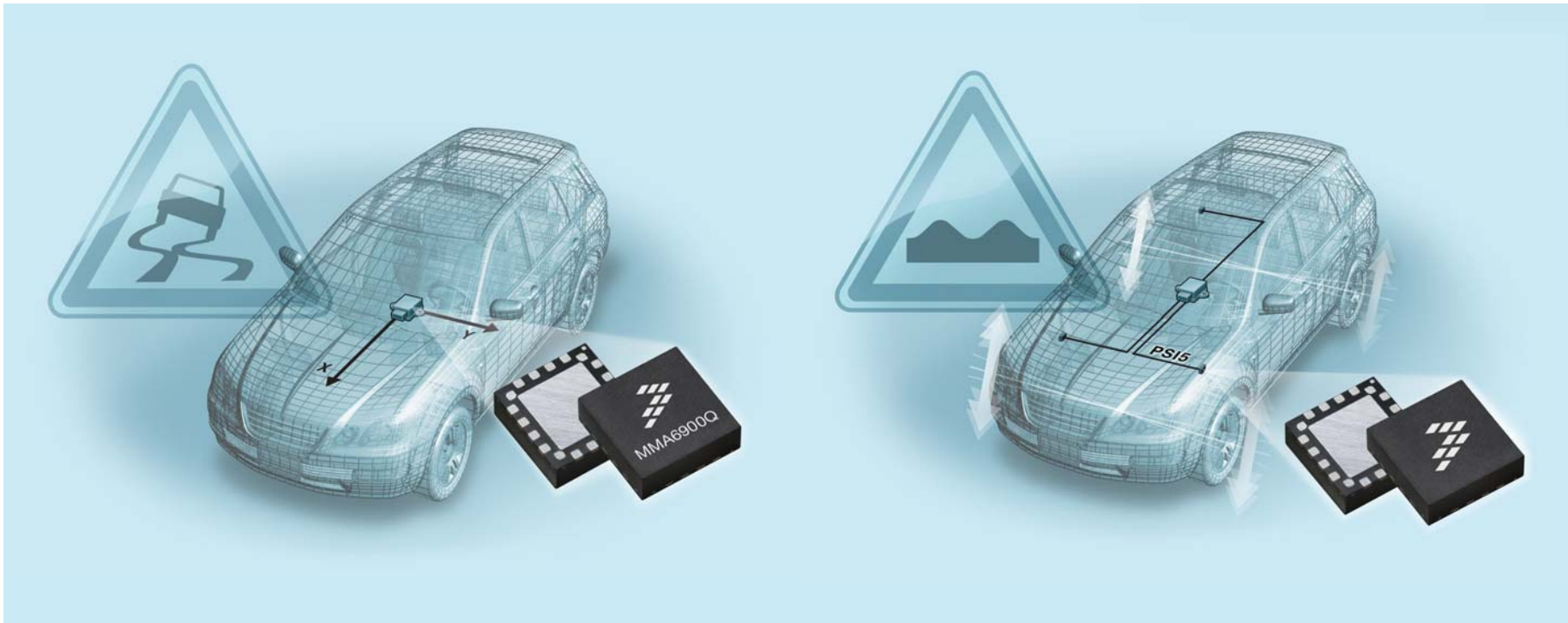

Product Offering for VDC and Suspension

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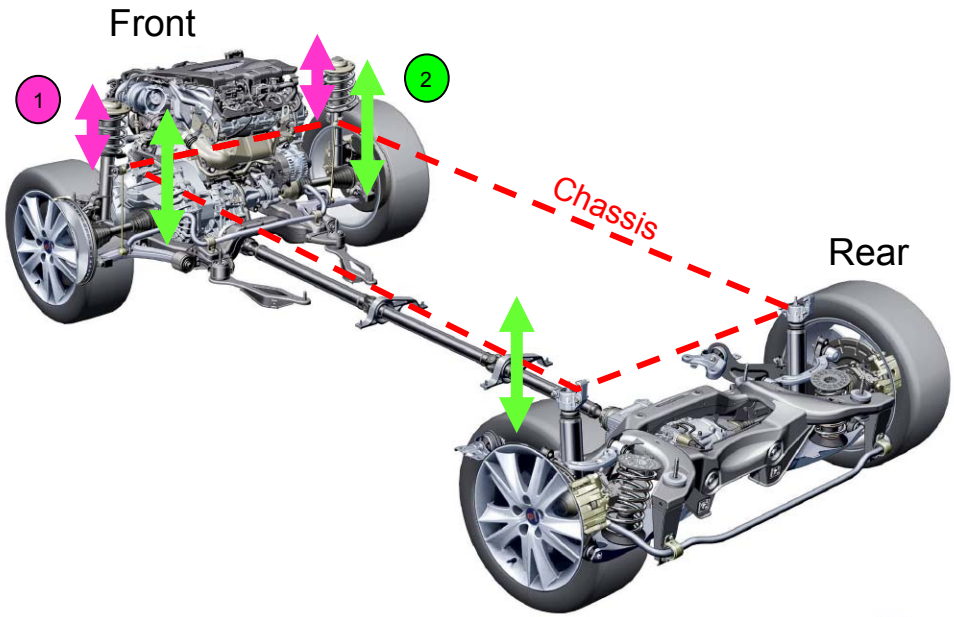
Inertial Sensors for Electronic Controlled Suspension

Without
Active Damping System

With
Active Damping System

Key function is to keep the car body stable through :

- **Chassis movement measurement and / or**
- **Wheel/damper movement measurement**



1 **Vertical wheel movement:**
Located directly on damper

2 x Low g sensors
Cut off frequency around 300Hz to 400Hz
G range: ±15g
Sensitivity error: 5% target

2 **Vertical body movement:**
Located on chassis

3 x Low g sensors
G range: ±2g
Cut off frequency around 100Hz
Sensitivity error: 5% target

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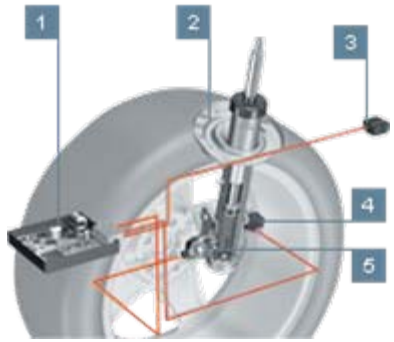
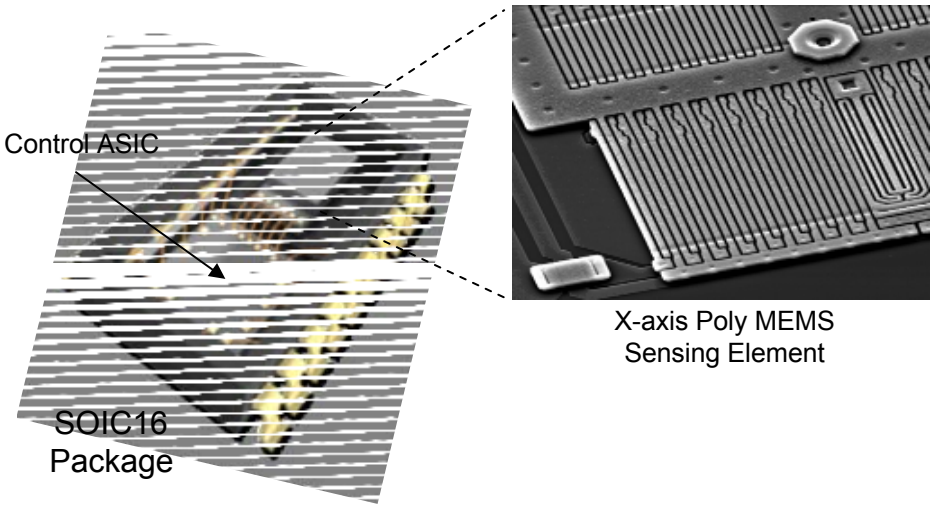
Suspension Low g Sensors

- Single X axis Family Sensors with analog output:
  - 2 poles filter
  - Low voltage detect
  - EPROM parity check status
  - Calibrated Self-test



Active Suspension system with low g sensors



X-axis Poly MEMS
Sensing Element

Part Number:

MMA2260EG	**± 1.5g**
MMA2240EG	**± 7g**
MMA2241EG	**± 10g**
MMA2242EG	**± 15g**

In Production

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PSI5 http://www.psi5.org

PSI5 used for Active Suspension

Sensor Interface Status

- Several Sensors Interfaces exists (PAS, DSI, Pegasus, etc...)
- Current Sensor Interfaces use 3 wires
  - Analog output does not offer enough immunity to interference
  - PWM output is EMC sensitive
- Market trend is going to digital interface

What is PSI5?

- PSI5 has been chosen by most car OEM for future Passive Safety applications
- PSI5 is an Open Standard and support various bus topologies (Cost reduction)
- Digital data transmission is safe and additional information can be added

What does it bring?

- Active suspension bus topology is similar to airbag satellite sensors
- PSI5 is a 2 wire current interface (reduce wiring & interference susceptibility)
- PSI5 power supply and data rate capabilities are sufficient for most driving dynamics sensors
- PSI5 synchromous mode can be used to acquire all wheel sensors datas at the same time
- Multiple sensors (wheel or chassis acceleration sensors, height sensors) can be connected to one PSI5 interface

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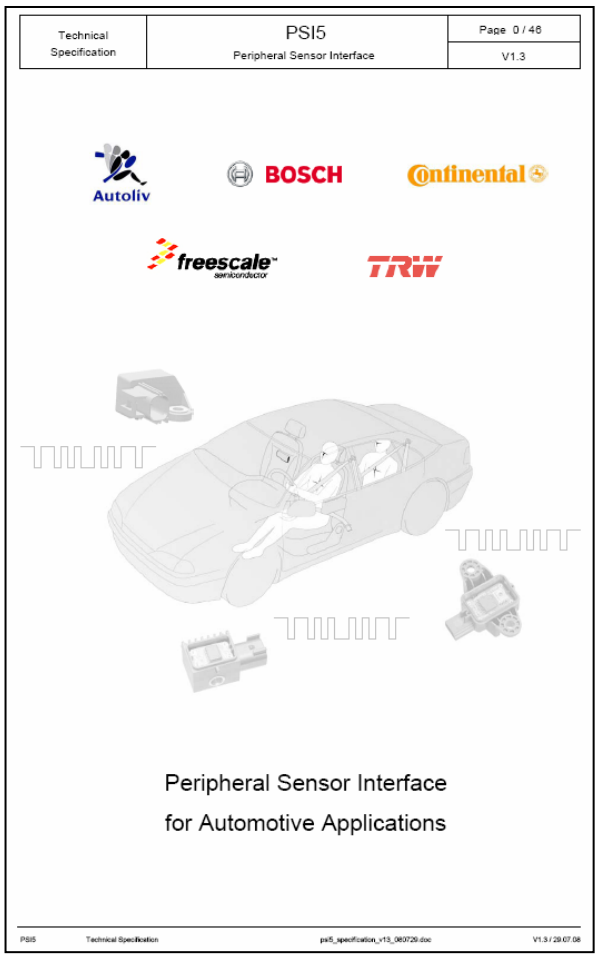
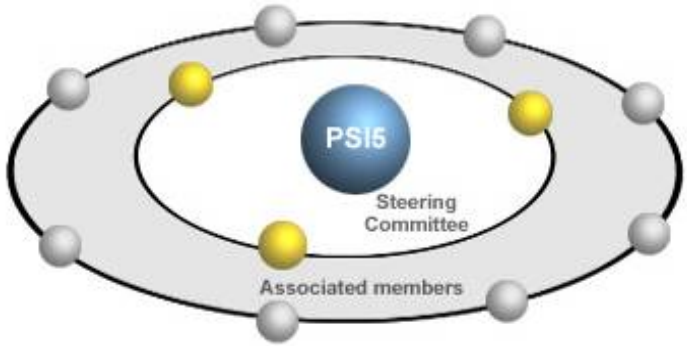
FSL Commitment to PSI5 Standard



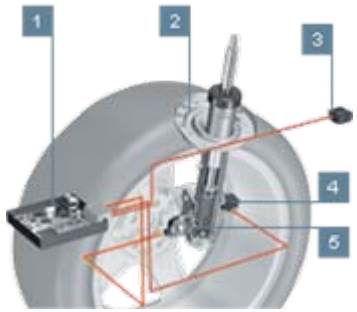
Extracted from www.PSI5.org page



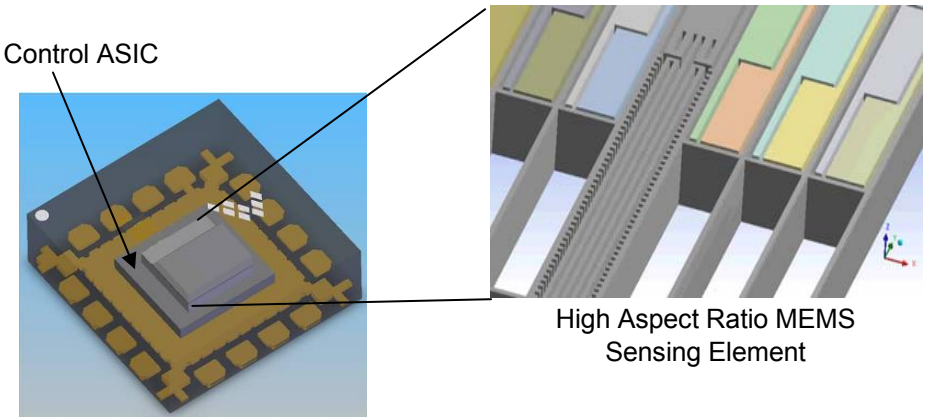
- Freescale is PSI5 Associated member since 2006
- As such, Freescale participes actively to the PSI5 consortium meetings with one representant.
- Tasks include:
  - Standard Specification Definition & Review
  - Development of Conformance Test
  - Implementation and promotion of PSI5 protocol

PSI5 Suspension Satellite Sensors

- System-in-Package (SiP) solution integrates board-level functionality in a single package:
  - Inertial sensing element
  - State Machine
  - Power supply
  - Communication protocols: PSI5 rev1.3



Active Suspension system with low g sensors



QFN Package

High Aspect Ratio MEMS Sensing Element

Part Number:

MMA52003Q	**± 3g**
MMA52015Q	**± 15g**

In development

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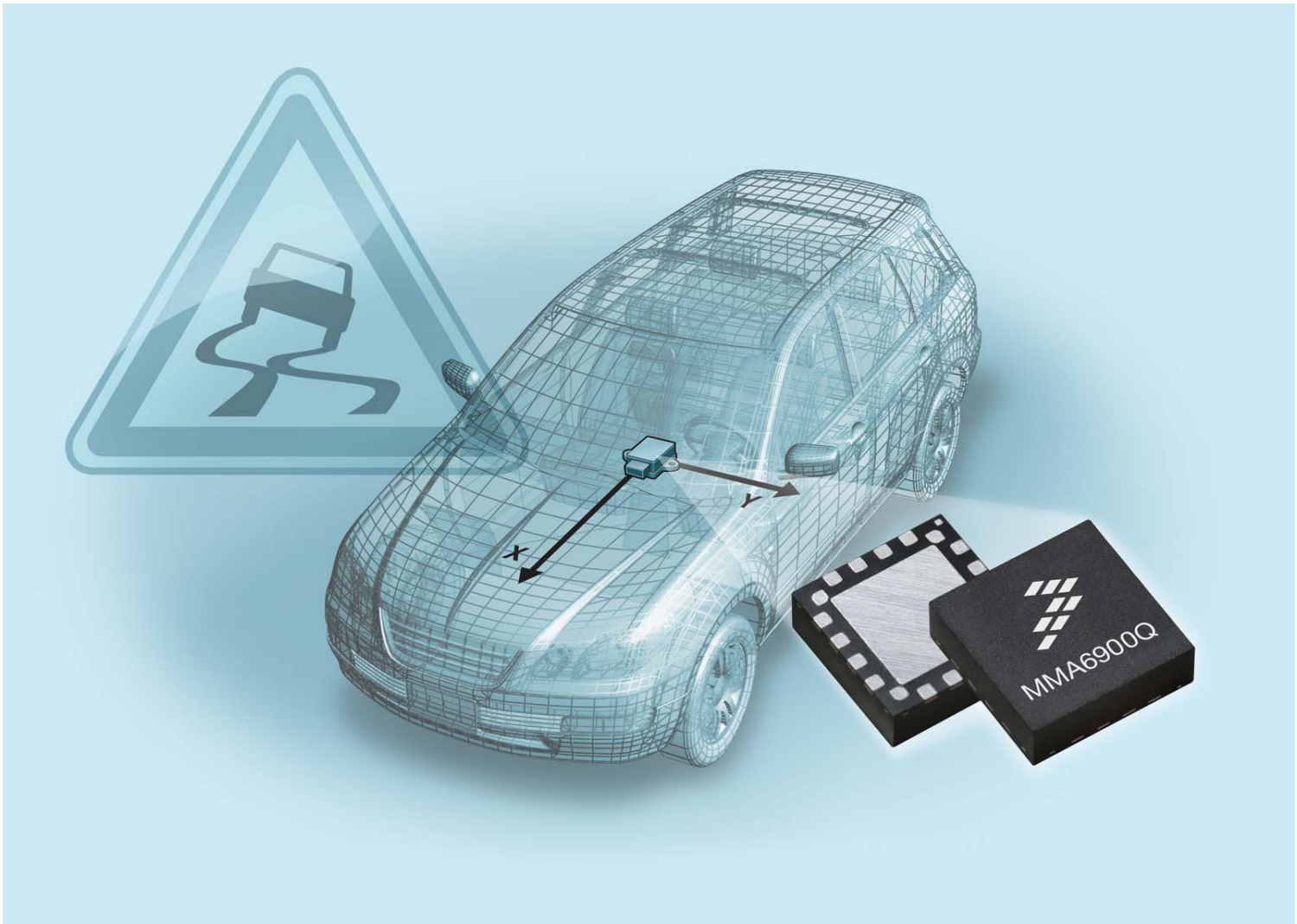
FSL Sensors in Vehicle Dynamic Control Application



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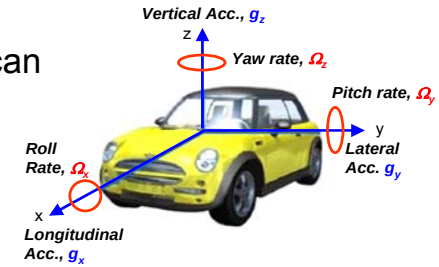
How does ESC Work ?

How does it work ?

- Electronic Stability Control (ESC) assist the driver in critical driving situations.
- ESC compares a driver's intended course with the vehicle's actual movement.
- When instability is detected, ESC automatically applies brakes to individual wheels and can also reduce engine torque to help keep you on track.

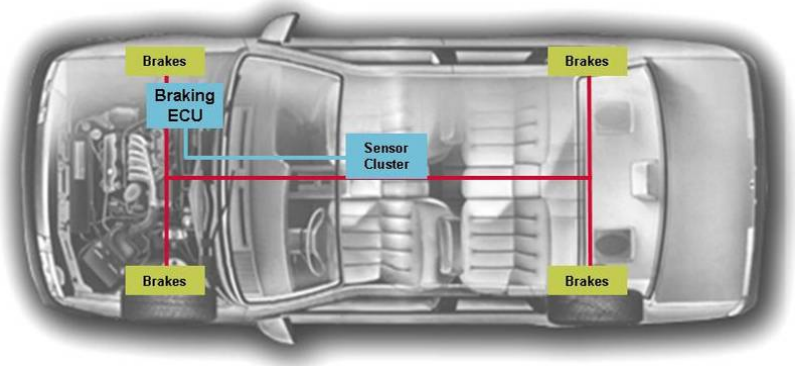


The ESC system relies on sensing inputs from:

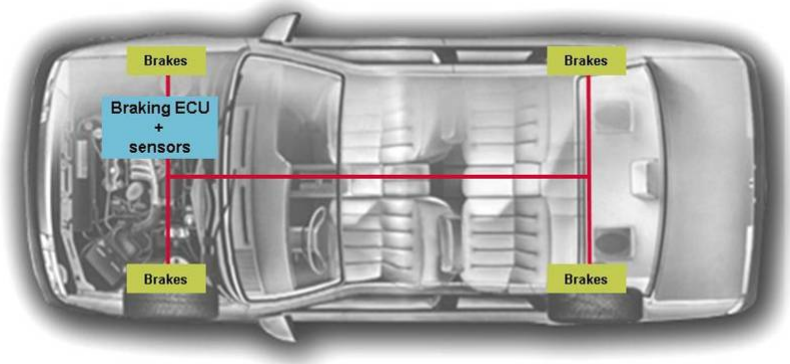
- Steering wheel angle sensor
- Wheel speed sensors
- Pressure Sensors
- **Yaw rate Sensor**
- **Acceleration sensor**

Various Sensors orientations are needed depending on the position in the car:
- In-plane Gyro + Z axis low-g (Embedded)
- Out-of-plane Gyro + Y low-g (Remote)

ESC Remote sensor cluster architecture



ESC Embedded sensor cluster architecture



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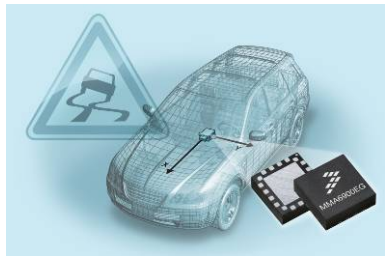
Vehicle Stability Control: Inertial Sensors

- Dual XY axis Sensors with fully digital signal processing:
  - Overdamped Inertial sensing element
  - Digital output (10 or 11 Bits)
  - Low offset accuracy over temperature (50mg)
  - 3.3V or 5V Power Supply
  - Bi-directional Self-test
  - Programmability (filters, ...)

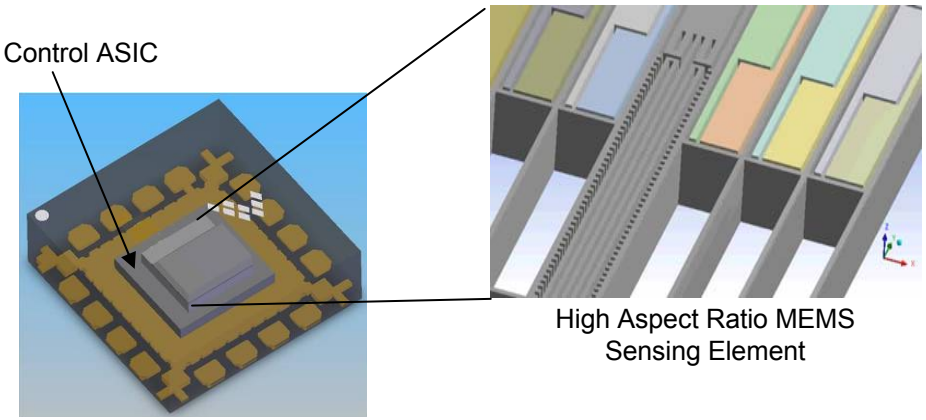


VSC Module

Car with and without VSC

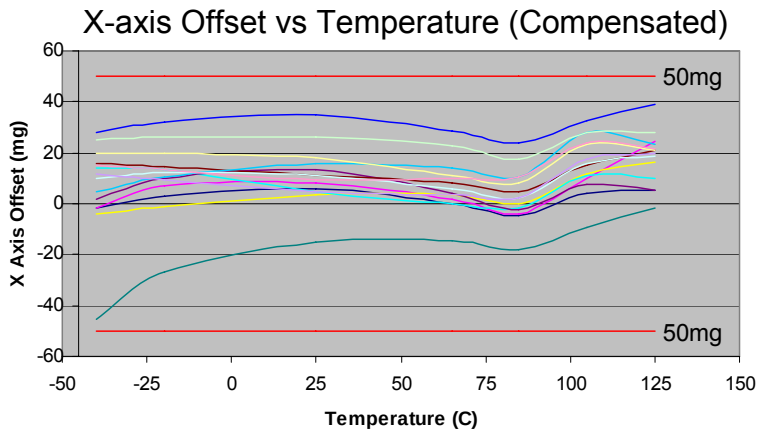
Part Number:

MMA6900Q ± 3.5g



QFN Package

High Aspect Ratio MEMS Sensing Element



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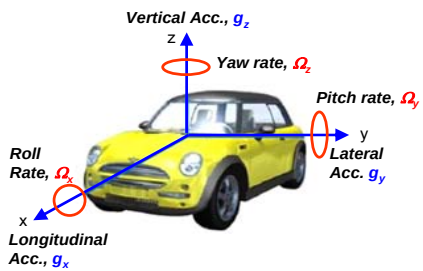
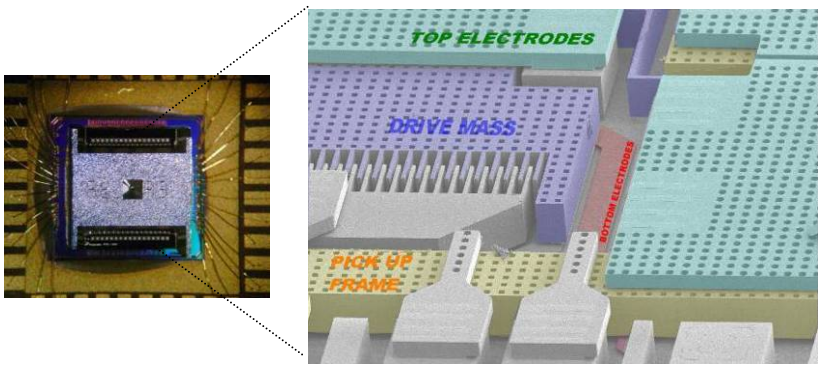
Vehicle Stability Control: Angular Rate Sensors

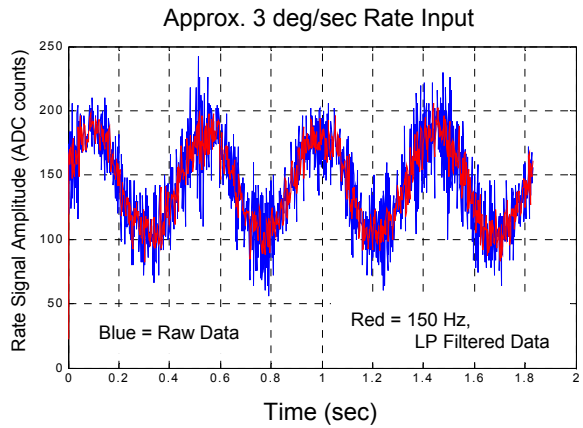
- **Angular Rate with fully digital signal processing:**
  - X-axis rate sensor: ± 100°/s to 300 °/s
  - Z-axis rate sensor: ± 100°/s to 300 °/s
  - Closed loop architecture – No Δf PEEKING
  - Digital Output (SPI) – 16 bit format
  - 3.3V or 5V Power Supply
  - Continuous Function Monitoring



Car with and without VSC



Coriolis based double mass balanced design



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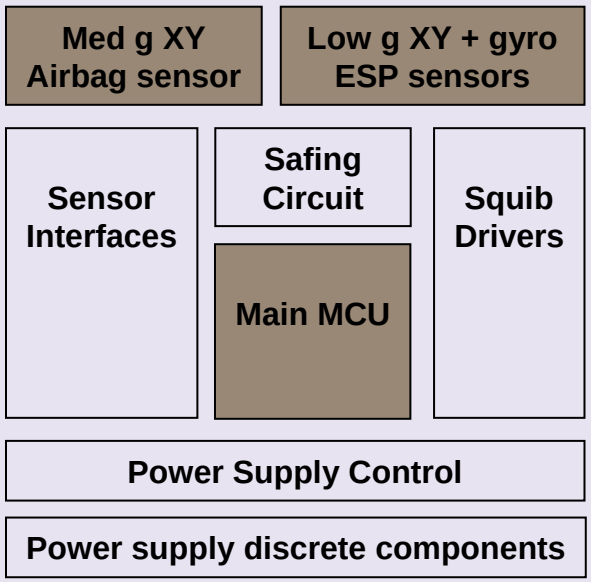
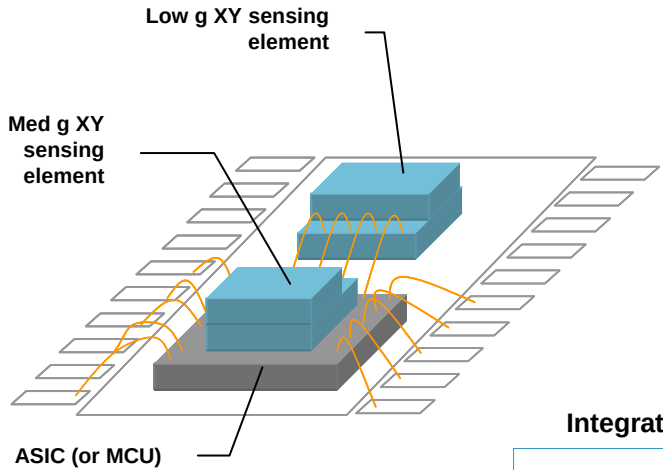
Long Term Vision: Further Integration Thanks to MEMS

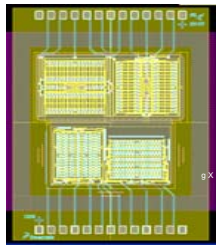
Passive & Active Safety module with discrete components



Sensor Possible integration

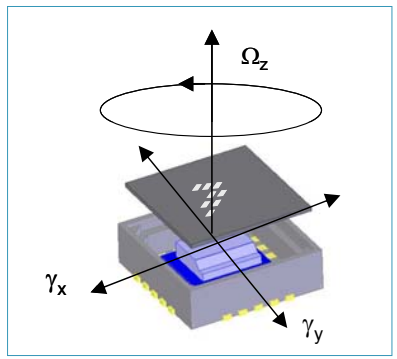
From a multi-component sensor cluster module to …





Multi-axis Sensing Element

Integrated 3 DOF Cluster



… A highly integrated multi-range and multi-axis inertial cluster.

For illustration purpose only

DoF: Degree of Freedom

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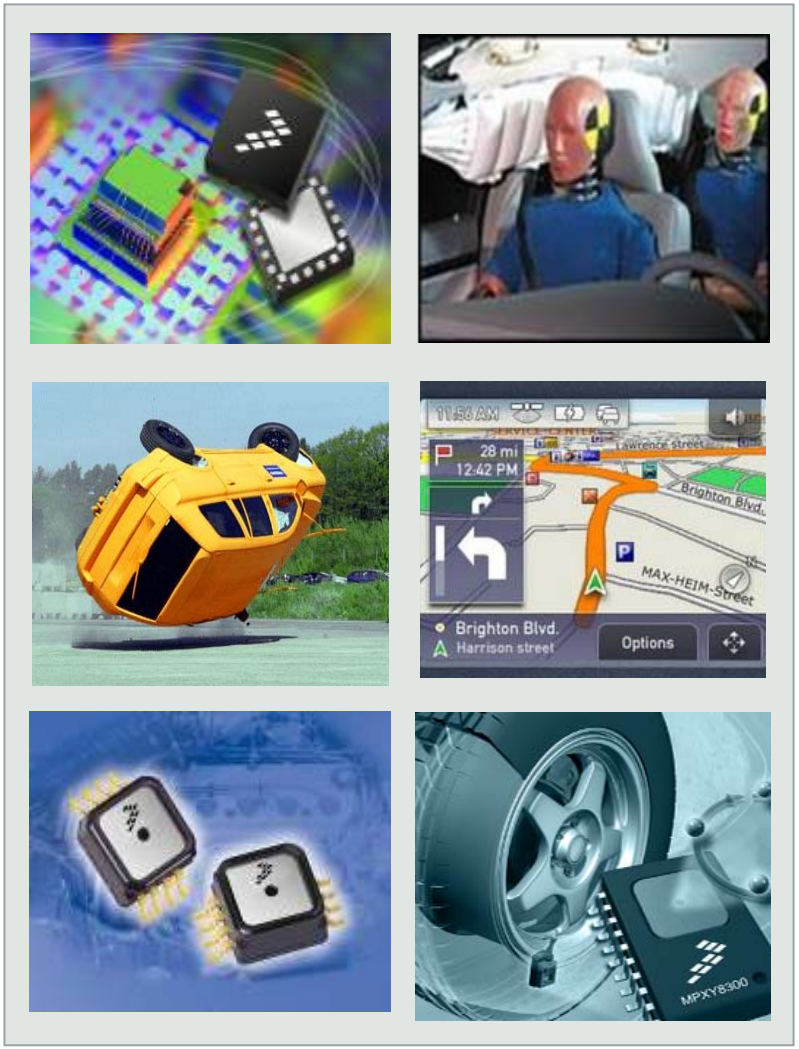
Conclusion

- Automotive trend is towards more Safety: Vehicle Dynamic Control (VDC) is mandated and Active Suspension is picking-up
- Freescale is a key player in automotive MEMS market
- Simulation & Modelling tools are key to develop the next generation of devices
- FSL develop solutions with PSI5 Satellite Communication
- Long term Vision: Complete System Integration with VDC (Gyro + Low g) + airbag sensors



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Thank you !

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