The World Leader in High Performance Signal Processing Solutions

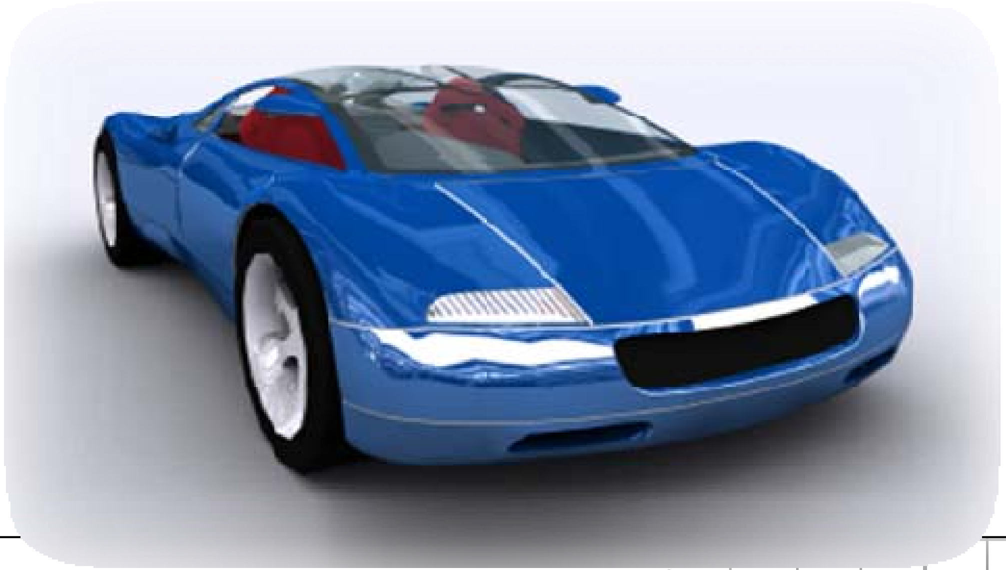
MEMS Inertial Sensors Monitor Vehicles in Motion

Automotive Electronics & Electrical Systems Forum
Stuttgart
6 May 2008

ANALOG DEVICES

Presentation Outline

- Automotive Safety System Mandates and Standards
- Challenges for Inertial Sensors
- Merging Safety Systems
- Safety System Architectures and Trends
- Safety Sensor Integration
- Automotive Electronics and Sensor Implications
- Summary



ADI In Automotive Safety
NHTSA ESC Mandate

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Our mission: Save lives, prevent injuries, reduce vehicle-related crashes

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In the News

NHTSA 09-06
Thursday, September 14, 2006

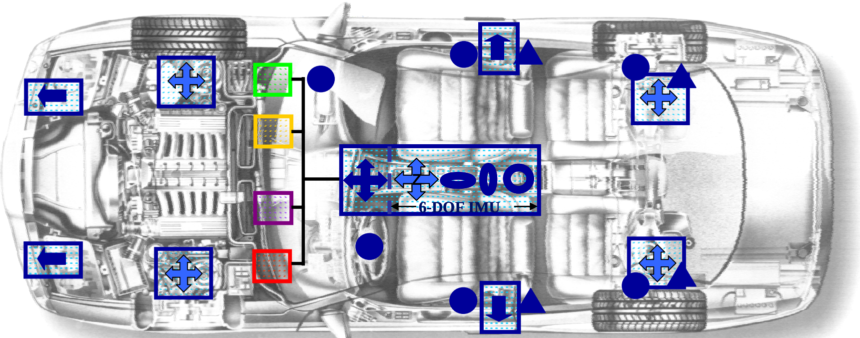
Contact: Rae Tyson
Telephone: (202) 366-9550

DOT Proposes Anti-Rollover Technology for New Vehicles

A new proposal to require auto manufacturers to install electronic stability control (ESC) as a standard feature on all new passenger vehicles has the potential to save more than 10,000 lives every year, the National Highway Traffic Safety Administration (NHTSA) announced today.

The proposed rule, announced today, would require all manufacturers to begin equipping passenger vehicles under 10,000 pounds with ESC starting with the 2009 model year and to have the feature available as standard equipment on all vehicles by the 2012 model year (September 2011).

Passenger Vehicles
Under 10,000 lbs by
September 1 2008
All Vehicles by
September 1 2011

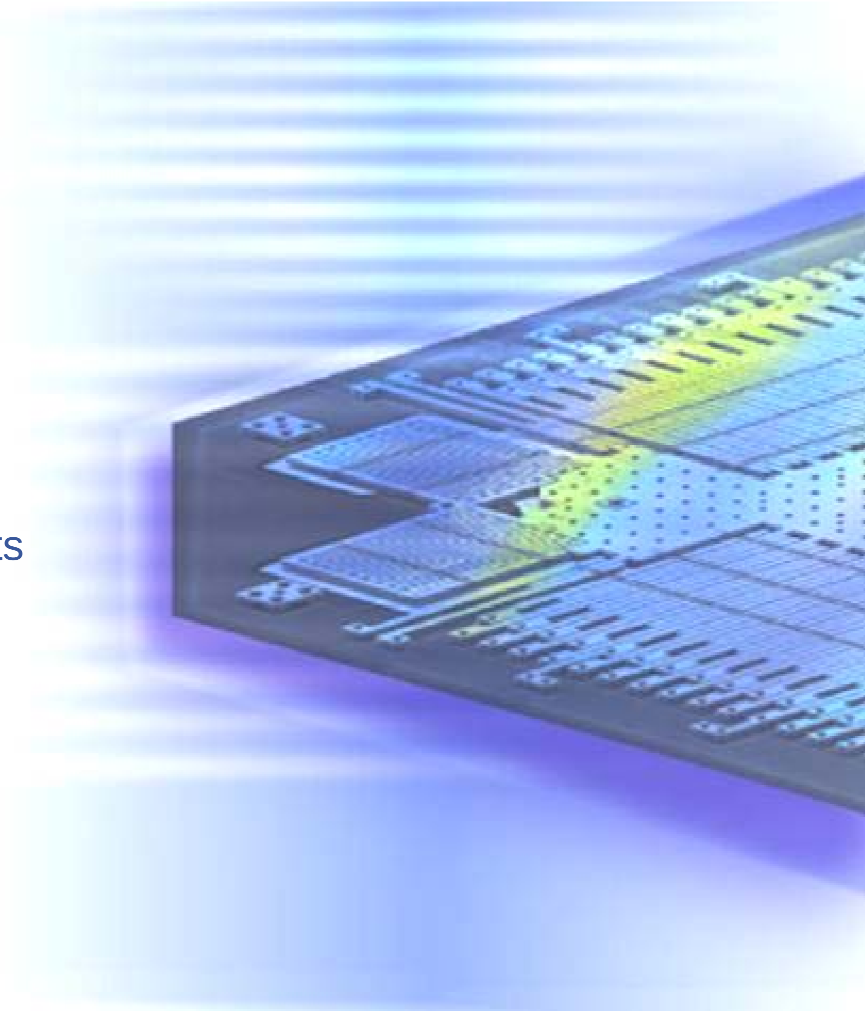


Safety Integrity Level Requirements

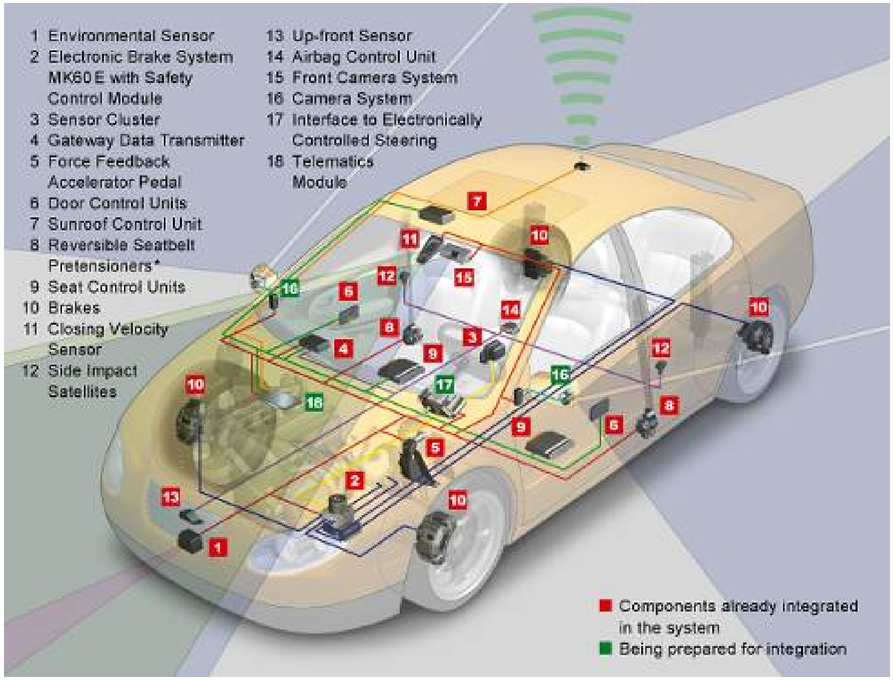
- Emerging EU trend for automotive safety systems to achieve Safety Integrity Level 3 (SIL3) requirements
  - IEC 61508
    - Functional safety of electrical/electronic/programmable electronic safety-related systems (E/E/PES)
      - SIL 1 through SIL 4
  - ISO 26262
    - ISO TC22 SC3 WG16 adapting IEC 61508 for automotive functional safety
      - ASIL A through D
- IEC 61508 SIL3 requirements
  - Safe Failure Fraction (SFF) > 99%
  - Probability of dangerous failure fraction per hour (PFH) < 10-7
- Achieving ASIL C compliance requires a holistic approach to system and product design
  - Requirements flow from OEMs to Tier 1's to component suppliers
    - Close collaboration between Tier 1's and critical component suppliers required for success

Challenges for Inertial Sensors

- **Tough safety standards**
  - **FMVSS210**
  - **FMVSS214**
  - **European NCAP**
  - **Allianz Center for Technology**
- **Harsh Operating Environment**
  - **Temperature Effects On Sensor**
  - **Overload**
    - Determining Between Crash vs. Misuse Events
  - **High-Voltage**
- **Demand for Increased Integration**
  - **More Robust Self-Test Concepts**
  - **More Discriminate Crash Detection**
  - **Compatible with multiple busses**
- **Low System Cost**



Active/Passive Safety System Integration Key Enablers



Source: Continental

- **Collision Warning and Preparation**
- **Pre-Crash Emergency Braking**
- **Lane Departure Warning**
- **Park Assist**
- **Rollover Prevention and Mitigation**
- **Adaptive Restraints**
- **Side Impact Integration System**
- **Electronic Stability Control**
- **Seatbelt Pre-tensioning**

Merging Safety Systems

Accident Avoidance & Mitigation

Active Safety

- Electronic Stability Control
- Adaptive Suspension
- Yaw / Roll Control

Driver Assistance

- Adaptive Cruise Control
- Lane Departure Warning
- Blind Spot Detection
- Lane Keeping System
- Parking Assist

The Intelligent Vehicle

- Collision Avoidance
- Accident Prevention
- Severity Reduction

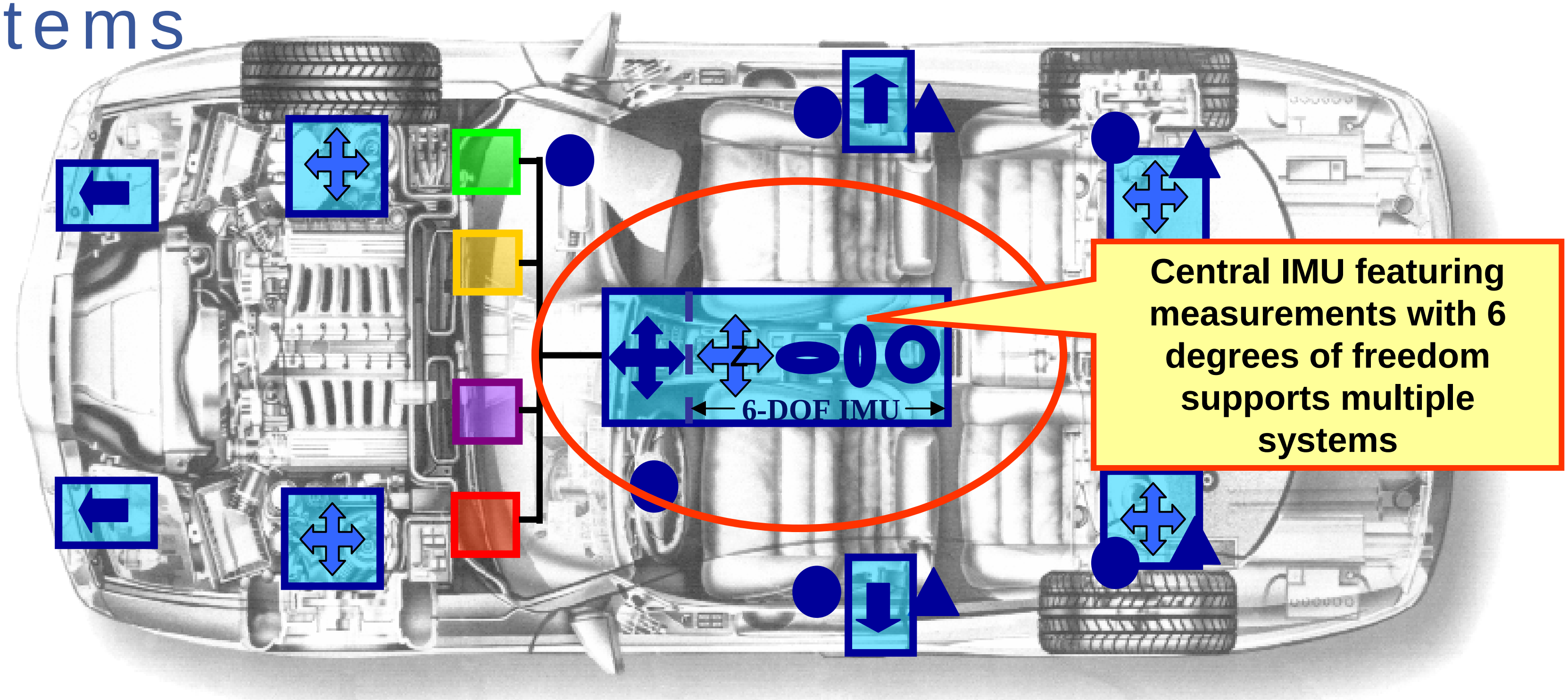
Passive Safety

- Airbags and Seatbelts
- Occupant Protection
- Pedestrian Protection

Communication

- Navigation Systems
- Visual/Audible Warning
- Inter-vehicle Communications

Future Systems Will Employ Inertial Measurement Units That Support Multiple Systems



Crash Detection System

Vehicle Dynamic Control System

Navigation/Driver Information System

Body/Chassis Control System

Satellite Sensor

Dual-axis airbag sensor

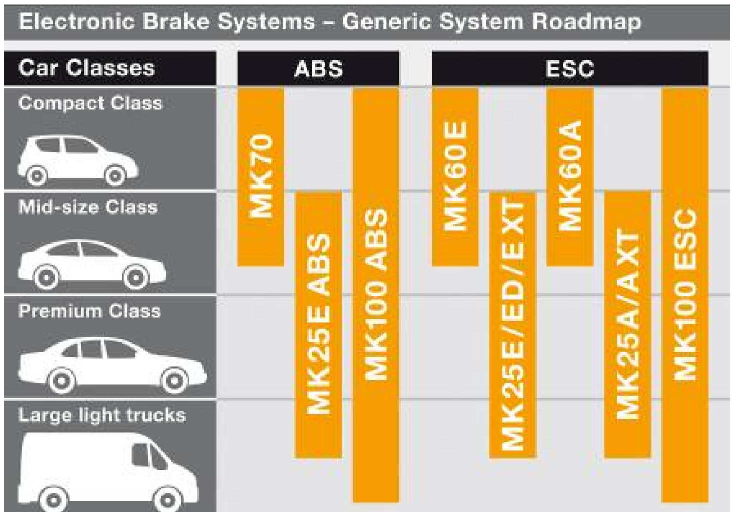
Low *g* chassis control sensor

Airbag

Seatbelt Pretensioner

Gyroscopes

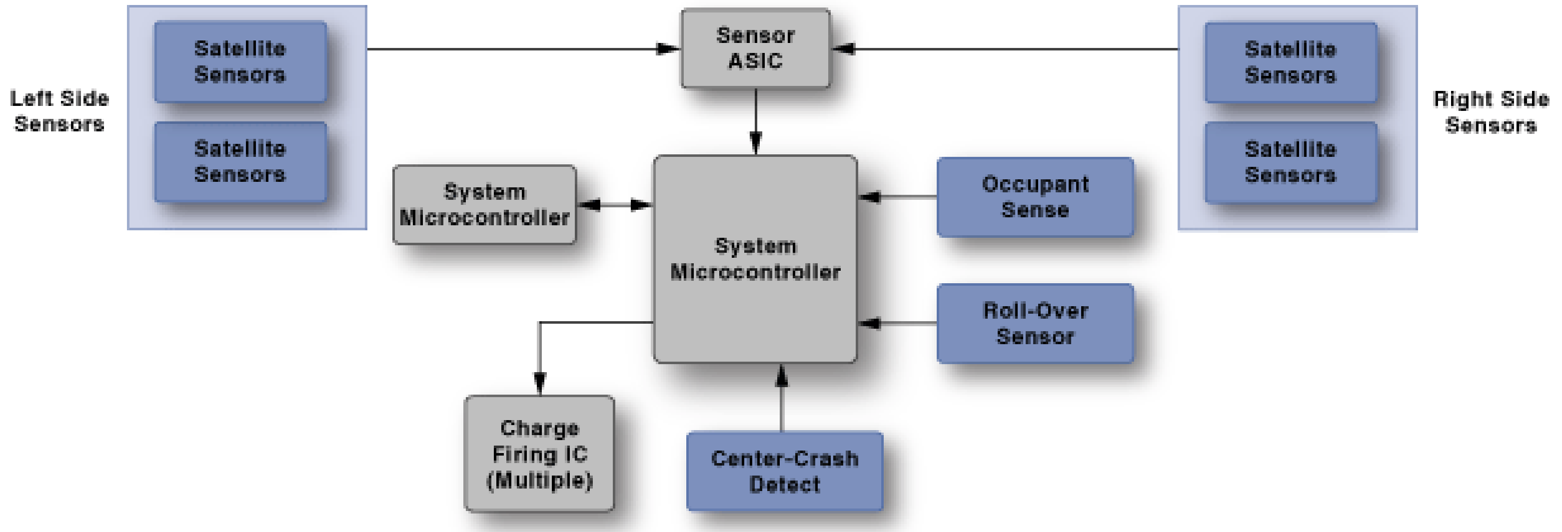
Modular Solutions Enable Scalability



Source: Continental

- Variety of safety and assistance functions can be incorporated into module
  - Active Rollover Protection
  - Trailer Stability Assist
  - Hill Start Assist
  - Adaptive Cruise Control
- Braking system is monitored by electronics which detect and configure components which have been exchanged
  - Eliminates time-consuming calibration procedures
- Integrating sensor cluster (yaw-rate and acceleration sensors) into brake control unit reduces components and interfaces
  - Reduces weight, size and co$t

Existing Safety System Architectures
Airbag Control Unit



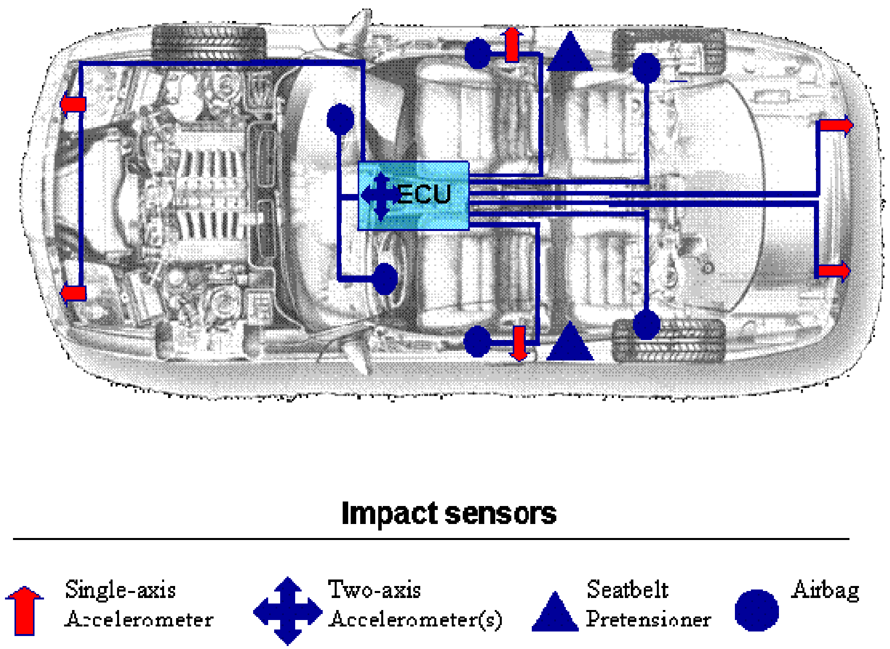
Other Key Components:

- Digital Potentiometer
- Power Management
- Signal Control
- Supervisory
- References
- Synthesizers

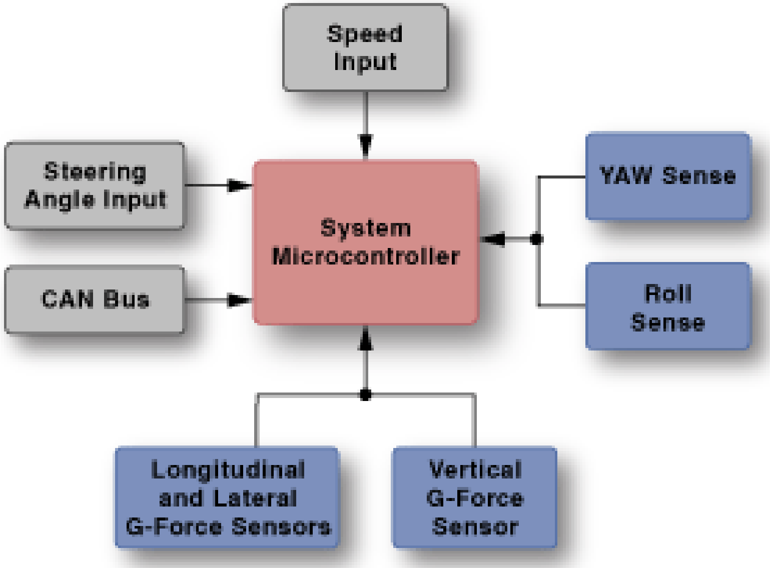
Crash Sensors

Continuous Improvement in Performance At “First Contact”

- **Crash sensing (passive safety) strives for two main objectives:**
  - More accurate crash discrimination
  - Safer and more effective deployment
- **Expanding awareness of vehicle environment**
  - More sensors per vehicle
  - Increased mechanical information
  - New kinds of sensors beyond accelerometers
  - Occupant size, out-of-position classification
  - Pedestrian safety
- **Mounting sensors closer to edge of the vehicle (frame rails)**
  - Earlier detection of collision
  - Know location of crash
  - Mutual safing
- **Links to other systems**
  - EDR (Electronic Data Recorder)
  - Telematics (eCall)



Existing Safety System Architectures
Electronic Stability Control Unit



Other Key Components:

- Digital Potentiometer
- Power Management
- Signal Control
- Supervisory
- References
- Temperature Sensors

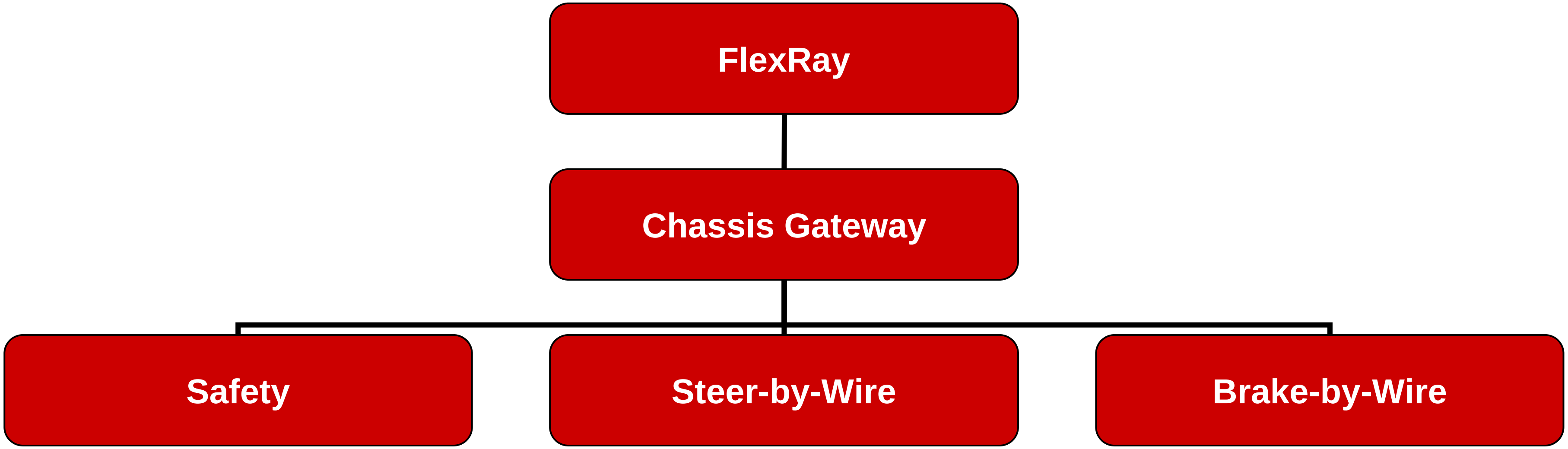
Integrated Safety Module: Crash + ESC
Emerging System Architecture

Source: Autoliv

- **FMVSS126 expands low-g sensor fit-rate in stability control applications**
  - **NHTSA estimates ESC will reduce single-vehicle crashes of passenger cars by 34% and single-vehicle crashes of SUV's by 59%, with a much greater reduction of rollover crashes**
  - **By 2012, 98% of new vehicles in Europe and 100% of new vehicles in the US will have ESC systems**
- **OEMs will integrate both Airbag and ESC in airbag control unit**
  - **Reduce two packages into single package able to cover both ESC and restraint accelerometer needs**
  - **Savings $30/vehicle**
- **All systems will have**
  - **Mid-g (20 g - 100 g) crash**
  - **Low-g (< 5 g) ESC**

Evolution in Automotive Networks

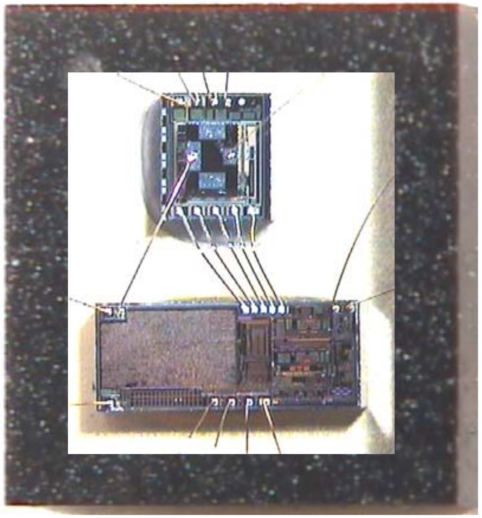
Application-Specific vs. Networked Sensors



- **Present direction to decrease number of ECU's**
  - **Possible decentralization of data processing to individual device**
  - **Individual ECU's and semiconductor content will need greater functionality and speed**
  - **System reliability depends upon that of individual ECU's**
  - **Specifications of semiconductors in resulting networks may change dramatically**
- **Vehicle Sensors are networked to provide motion data to various safety systems**
  - **Star (e.g., BMW 7-Series Airbag using ByteFlight), Ring or IMU configuration**
- **FlexRay becoming standard for more advanced control applications**

Future of MEMS Inertial Sensors in Vehicles

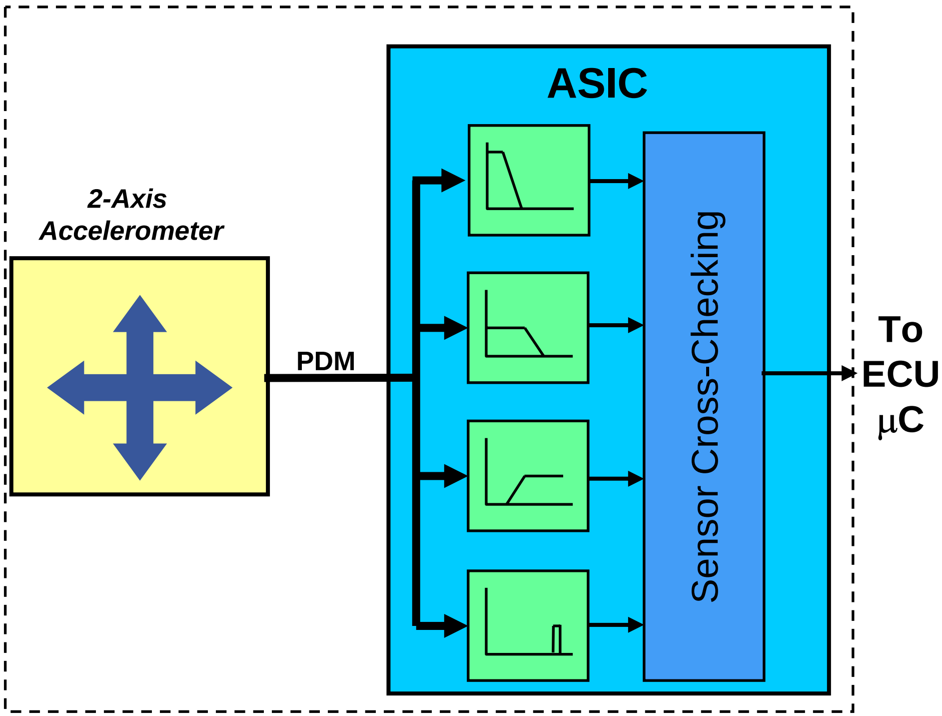
- **System designers are re-thinking current stand-alone sensor architectures in favor of integrating additional functionality of, e.g., an Airbag Control Unit into one single ASIC/ASSP:**
  - Receiver (for sensor satellites)
  - SPI output for communication with µC
  - Squib driver
  - Watchdog
  - Power management for entire ACU
  - Clock
  - NVM for diagnostics/calibration
  - PSI5
  - CAN or FlexRay interface



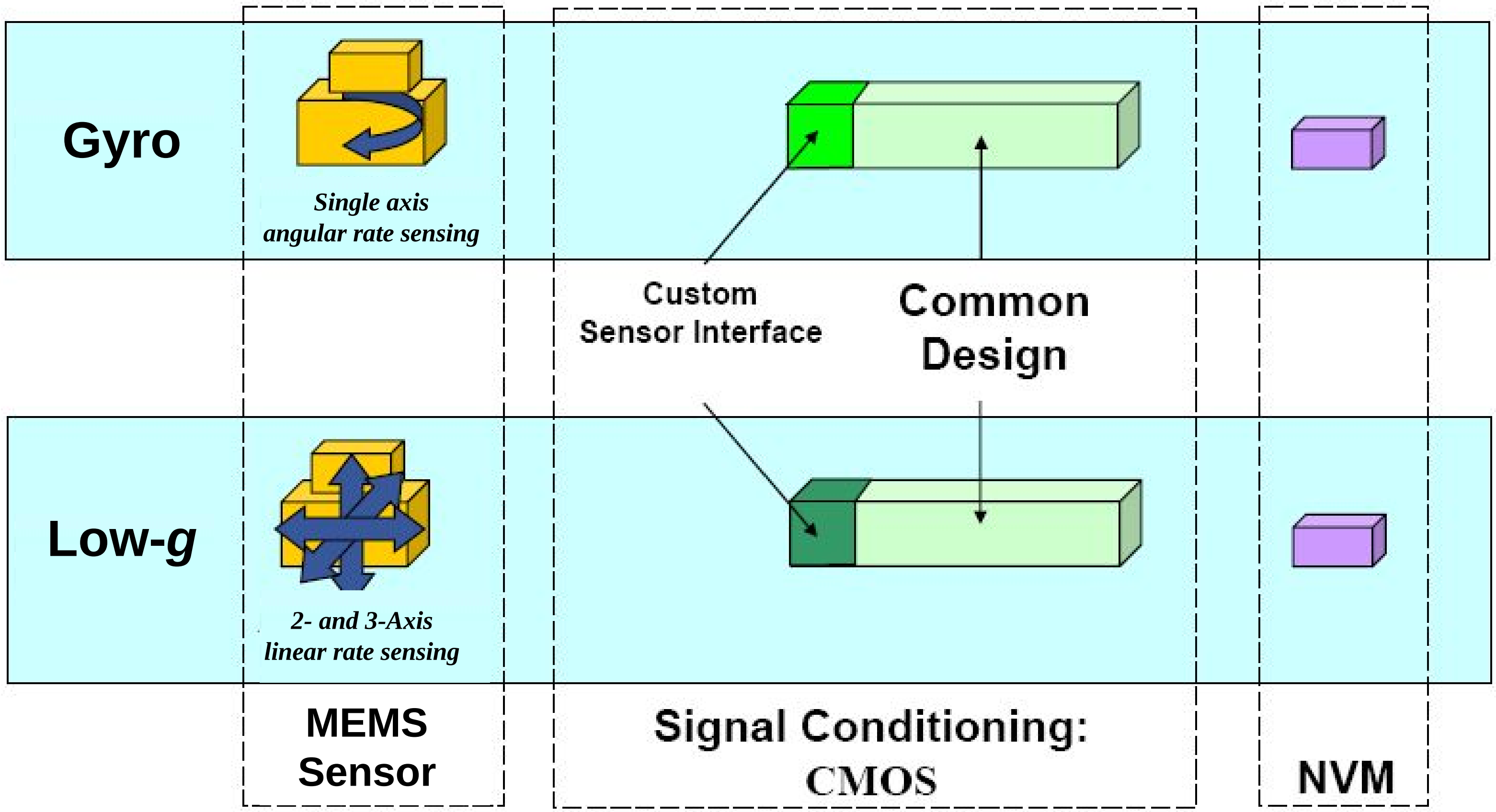
- **This sensor ASIC/ASSP model is being evaluated by automotive OEMs and will become crucial to cost control as well as to conserve electronics real estate without compromising performance**

Active/Passive Safety Sensor Integration
ESC and Crash Acceleration Sensing in Single Package

- Crash high-g and VSC low-g in a single package
- Facilitate integration of active and passive safety
- Reduce total system cost
- Increase usage of digital signal path to enhance sensor performance
- Digital SPI communications
- Enhance performance via communication with other sensors
- Continuous self-test/status pin
- Low power consumption
- Small plastic packaging



Active/Passive Safety Sensor Integration
ESC Angular Rate and Acceleration Sensing in Single Package



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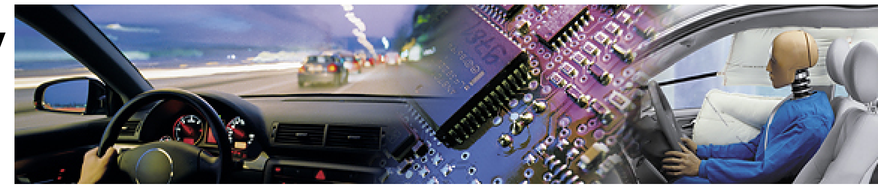
Automotive Electronics Trends

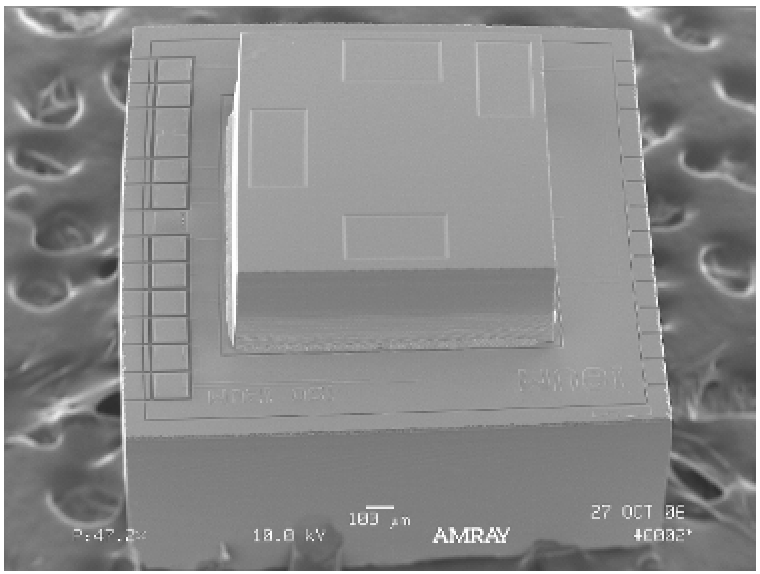
- **Increasing System Complexity**
  - **Increasing functionality**
    - Comfort, Entertainment, Safety
  - **Proliferation of safety-critical functions**
    - ABS, ESP, EPS
  - **Networking between subsystems**



Source: Continental

- **Electrical System Robustness**
  - **More stringent EMI and ESD requirements**
  - **Quality and reliability**
- **New Technologies and Requirements**
  - **Vehicle-to-Vehicle and Vehicle-to-Road Communication**
  - **Collision avoidance**
- **Increasing Cost Pressure**
  - **Electronics contribute significantly to vehicle manufacturing costs**

Safety Sensor Integration and Networking
Emerging Requirements



- **Size**
  - **Small form factor necessary for flexible placement and integration of multiple sensors**
  - **Reduced hardware complexity**
- **Orientation**
  - **X-Y-Z Accelerometers and Roll-Yaw Gyros needed to cover full array of implementations**
- **Features**
  - **Modular partitioning to merge active and passive safety**
  - **Digital functionality and features**
  - **3.3 V and lower operation**
  - **More digital signal processing**
  - **Support new communications and networking standards**

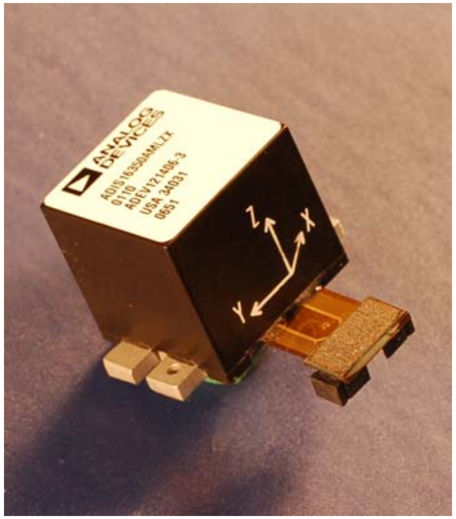
Safety Sensor Integration and Networking

Emerging Requirements

- **Quality and Reliability**
  - **Zero Incident Target**
  - **Higher Device Yields**
  - **Enhanced Self-Test and FMEA characteristics**
- **Robustness**
  - **Operation in harsh environments with intense vibration and high temperature**
- **Ease of Manufacturing**
  - **Eliminate module-level calibration**
  - **Increased configurability, e.g. filter and g-ranges**

MEMS Automotive Inertial Sensor Integration Summary

- **Automotive customers are expressing strong interest in combined sensors and IMUs**
  - **Primarily interested in gyros and low-g accelerometers**
  - **Reduced sensor packaging volume**
  - **Perceived cost saving based on reduce package cost**
- **Numerous approaches to combined sensors/IMUs**
  - **Module level**
    - Packaged sensors
    - Sensor Die
  - **Component level**
    - Single package
    - Functional equivalent to a single package
    - Angular Rate and Acceleration from a single sensor structure
- **Packaging volume reduction dependent on sensor technology and integration strategy**
- **Future automotive safety systems will require close collaboration between OEMS, Tier 1s and critical component suppliers**
  - **Fail-safe and ASIL C compliance strategies and IP**
  - **System-level trade-offs to optimize system performance and cost**



Presented By:
Kristen Manon McNair Hopper
European Automotive
Customer Marketing Manager

Analog Devices, Inc.
Micromachined Products Division
21 Osborn Street
Cambridge, MA 02139-3556
+1 617 761 7645
kristen.mcnair@analog.com

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