Trends in Automotive Sensors

Matthias Metz
Bosch RTC Palo Alto

Based on material by
Automotive Electronics Sensor Center, Reutlingen, Germany
Trends in Automotive Sensors

Car without Sensors
Trends in Automotive Sensors

Car with Sensors

Drivetrain
- Pressure sensor (Electronic transmission control, motronic)
- Manifold absolute pressure sensor (Electronic diesel control, motronic)
- Mass air flow sensor (Motronic)
- Oxygen sensor (Fuel injection system, common rail)
- Radial speed sensor (Electronic transmission control, motronic)
- Acceleration sensor (Vehicle dynamics control, motronic)
- Angular rate sensor (Vehicle security sensor)
- Angular rate sensor (Torque sensor)
- Angular rate sensor (Angular rate sensor)

Convenience
- Angular rate sensor (Navigation)
- Humidity/temperature sensor (Heating and air conditioning control)
- Pressure sensor (Central locking system)
- Main sensor (Headlight control)
- Ultrasonic distance sensor (Rear proximity warning system)

Safety
- Radar distance sensor (ACC system)
- Tilt sensor (Vehicle dynamics control, motronic)
- High pressure sensor (Vehicle dynamics control)
- Acceleration sensor (Airbag)
- Seat occupancy sensor (Airbag)
- Yaw rate sensor (Vehicle dynamics control)
- Angular rate sensor (Vehicle dynamics control, motronic)
- Angular rate sensor (Vehicle security sensor)
- Angular rate sensor (Radial speed sensor)

Bosch RTC
Contents

Systems, sensors and their impact

Trends

Summary
Persons killed in traffic accidents 1970 and 2003*

* Germany

\[ \text{Persons killed in 1970: 21,332} \quad \text{Persons killed in 2003: 6,613} \]

- 2003: ~54 Mio. Cars
Overview Restraint System

- Out-Of-Position Sensor (OOP)
- Occupant classification sensor
- Child Seat Switch
- Peripheral Airbag Sensor
- Weight Sensor
- Central ECU with Acceleration Sensor(s) and integrated Roll-Over Sensing
- Bus Architecture

Electronics/Sensors
Actuators
Trends in Automotive Sensors

Electronic Stability Program ESP
Sensors for Electronic Stability Program

- Steering Angle
- Yaw Rate
- Acceleration
- High Pressure
- Wheel Speed
Emission Regulations in Europe

- CO
- HC
- NO_x
- HC+NO_x


0 10 20 30 40 50 60 70 80 90 100

ECE R15/0 15/01 15/02 15/03 15/04 R83/01 EU I EU II EU III EU IV
Gasoline Direct Injection

Trends in Automotive Sensors

Bosch-RTC

GS/VSA
6161

02/25/2004

Bosch-RTC
Trends in Automotive Sensors

Silicon Micromachined Sensors
Milestones: MEMS at Bosch

- **80s**  MEMS research activities
- **1988** Development section for MEMS
- **1992** Deep trench process developed at Bosch Research
- **1993** First volume MEMS-Product: Pressure sensor
- **1995-98** SOP mass flow sensor, accelerometer, gyroscope
- **1997** Start of component sales to external customers
- **1999** Research Center Palo Alto founded
- **2003** Department for MEMS-products in new segments
BOSCH - MEMS Manufacturing Volume

Year

Turnover MEMS products 2003:
> 400 Mio EUR
Trends in Automotive Sensors

Systems, sensors and their impact

Trends
Commodity

Summary
Cost trend for yaw rate measurement

- Steel macromechanic
- Silicon bulk/surface micromachining

ESP-Volume (Germany)
Trends in Automotive Sensors

Cost brake down of a micromachined sensor

![Image of a micromachined sensor]

- Packaging and Test
- Evaluation
- Sensor Element

<table>
<thead>
<tr>
<th>Component</th>
<th>Today</th>
<th>ASIC-Shrink</th>
<th>Optimized Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaging and Test</td>
<td>30%</td>
<td>30%</td>
<td>20%</td>
</tr>
<tr>
<td>Evaluation</td>
<td>45%</td>
<td>30%</td>
<td>20%</td>
</tr>
<tr>
<td>Sensor Element</td>
<td>25%</td>
<td>25%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Legend:
- Blue: Packaging and Test
- Purple: Evaluation
- Yellow: Sensor Element

Bar chart showing cost breakdown:
- Today: 30% Packaging and Test, 45% Evaluation, 25% Sensor Element
- ASIC-Shrink: 30% Packaging and Test, 30% Evaluation, 25% Sensor Element
- Optimized Technology: 20% Packaging and Test, 20% Evaluation, 20% Sensor Element
Technology impact on the housing
(yaw rate sensors)

bulk/surface micromachining

Ceramic carrier on steel

Surface micromachining, stress insensitive design

standard mold package
Trends in Automotive Sensors

Triaxial Low-g Sensor

- X, Y, Z - Axis
- Silicon surface micromachining
- 2 chip approach
- Digital signal evaluation
- SPI-Interface
- Full self test capability
- MLF package: footprint 36mm², height 1.45mm
Trend: Commodity Technology

- Silicon micromachining is well established for automotive sensors
- Most sensors have become commodities with high pressure on manufacturing costs
- Today's micromachining processes are cost-optimized
- The development of new sensor processes should allow cost reduction for the evaluation circuits, packaging and testing
Trend: Commodity Sensor Components

- Multi-functional sensors with
  - separate sensor elements
  - separate digital evaluation circuit
  are flexible, cost optimized and have a short time to market

- Packaging technologies have become the key to attractive manufacturing costs
Trends in Automotive Sensors

Systems, sensors and their impact

Trends
Commodity
Legislation

Summary
Weight Sensor: iBolt™ - Occupant classification
iBolt™ - Occupant classification

**Characteristics:**
- Measures the occupant weight
- Occupant classification according to US regulation FMVSS208.
- Integrated into the seat structure

**Benefits:**
- No H-point shift
- Standardized Sensor
- Integrated overload protection
- Design flexibility regarding connector

![Load applied through seat linkage](image)

Seat track
**iBolt™ - Occupant classification**

- **F = 0 N: gap open**
- **F => 1000 N: gap closed**

**Bi-directional measurement:**
- Compression & tension

**Integrated overload protection**
Trends in Automotive Sensors

Systems, sensors and their impact

Trends

Commodity
Legislation
Increased or new system performance

Summary
Trends in Automotive Sensors

Active Safety

Passive Safety

Driver Assistance

ESP
Brake Disk Wiping

New functions based on existing systems, not: new systems!

CAPS
Combination of Active & Passive Safety

Park Assistant
ACC
Video Functions

Crash Sensing
Rollover Sensing
Pedestrian Protection
iVision

Bosch-RTC

02/25/2004
Sensorcluster

- Bosch-RTC
- Engine Mgmt
- Theft Protection
- Airbag
- Navigation
- ESP
- Microcontroller

Selftest Plausibility
Kinematic-data set
Example for Sensorcluster

- Yaw Rate z-Axis 100°/Sek / < 0,1° Sek / 50Hz
- Yaw Rate y-Axis 100°/Sek / < 0,1° Sek / 50Hz
- Acceleration x-Axis 1,8 g / < 0,01g / 50Hz
- Acceleration y-Axis 1,8 g / < 0,01g / 50Hz
- Plausible signals up to overload 35g
- Internal check of signal plausibility
- CAN-Interface

- Application:
- ESP, Roll Mitigation, Hill - Hold
Trends in Automotive Sensors

Surround Sensing

- **Long Range Radar (Lidar)**
  - Ultra long
  - 1 m to ≤150 m

- **Infrared**
  - Night vision
  - range ≤ 200 m

- **Video**
  - Medium
  - 0 to ≤ 80 m*

- **Short Range (Radar, Lidar)**
  - Short
  - 0,2 to ≤ 20 m

- **Ultrasonic**
  - Ultra short
  - 0,2 to ≤ 1,5 (2,5) m

* object detection up to 80 m

02/25/2004
Sourround Sensing: Video Modul

Specifications

- Resolution ≥ 640 x 400 pixel
- Distance Range Fixfocus, 2m ... ∞
- Viewing angle horizontal ± 22.5°
  vertical ± 12.5°
- High dynamic range > 110 dB
- Camera is sensitive at day and night
- Mounting behind windscreen, small size

Application

- Traffic sign recognition
- Night Vision
- Lane Departure Warning
Trends in Automotive Sensors

Trend: Increased System performance

➤ Extreme pressure on manufacturing costs
➤ Sensor clusters will reduce the number of sensors necessary
➤ Linkage of today independent systems will increase safety
➤ Sensor clusters will simplify the linkage
➤ Radar, video and infrared sensors will enable systems in future to actively avoid accidents
➤ Legislation creates large markets for sensors but with high pressure on manufacturing costs (e.g. weight sensor, tire pressure monitoring)
Summary

Development of automotive sensors needs …..

- Exact knowledge of the system requirements

- An overall optimization of the sensor concept: technology, evaluation, package and testing

- The realization of the most cost efficient concept with the desired performance