INNOVATIONEN MEMS-BASIERTER SENSOREN BEI BOSCH

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Innovations

What are Innovations?

Wikipedia: 
“[…] innovation takes place through the provision of more-effective products, processes, services, technologies or business models […]”
Innovations

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Wikipedia:
“[…] innovation takes place through the provision of more-effective products, processes, services, technologies or business models […]”

!!!

* Boiling 1 cup (235ml) vs 1 litre
** one cup is equal to 235ml of water
MEMS Sensors
What are MEMS?

Micro-Electro-Mechanical Systems

- MEMS are miniature systems that combine tiny mechanical structures with electronic circuits. Typical individual structures have a size of a few µm.

- The MEMS sensor element is usually packaged together with an ASIC and made into one unit, e.g. into an LGA package.

| 1 | MEMS |
| 2 | ASIC |
| 3 | Decoupling unit |
| 4 | Bonding wires |
| 5 | Printed Circuit Board (PCB) |
Market overview
Multitude applications for MEMS sensors

Safety System
Mobile
Imagine
Health & Fitness
Motor Management
Home Application
Industrial & Logistics
Smart Systems
MEMS Sensors
Consumer Applications

- Motion sensing
  - Step counting
  - Activity monitoring
  - Power management
  - Free speech profile
  - Portrait / landscape

- HMI - User Interface
  - Tab / menu control
  - Gesture recognition
  - Gaming consoles
  - Microphones
  - AR/VR devices

- PND - Navigation
  - Speed and distance estimations
  - Altitude detection
  - Orientation
  - Context awareness
  - Location based services

- Environmental sensor
  - Gas and air quality
  - Beeing recomendations
  - Weather forecats
  - Smart home
  - Humidity
  - Temperature
MEMS Sensors
More than 50 MEMS sensors per car

Passive Safety
1. High G acceleration sensors for AB-ECU and eCall
2. Rollover sensor for Airbag ECU
3. Occupant weight sensors or pressure sensors
4. PTS - Pedestrian tube sensors
5. UFS - Upfront sensors
6. PPS - Peripheral pressure sensors
7. PAS - Peripheral acceleration sensors

Active Safety
8. Inertial sensors for ESP, RSC, RoSe
9. MM - Sensor cluster for ESP (accel. & gyro.)
10. High pressure sensor for ESP
11. Low-g acceleration sensors for active suspension
12. TPMS-Tire pressure monitoring system

Power Train
13. MAP - Manifold air pressure
14. BAP - Barometric air pressure
15. Medium Pressure for transmission
16. Mass flow sensor
17. High pressure sensor for fuel injection
18. Tank pressure sensor

Comfort Functions
19. Inertial sensor for navigation
20. Motor damping / noise cancellation
21. Microphones
22. Night vision
23. Gas / air quality and humidity
24. Car alarm
MEMS Sensors
More than 50 MEMS sensors in 1 car

<table>
<thead>
<tr>
<th>10 Sensors</th>
<th>27 Sensors</th>
<th>18 Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engine management</strong></td>
<td><strong>Active and passive safety</strong></td>
<td><strong>Comfort</strong></td>
</tr>
<tr>
<td>1 Mass flow sensor</td>
<td>2 High-g accelerometers for airbag ECU</td>
<td>2 Pressure sensors for transmission</td>
</tr>
<tr>
<td>1 Barometric air pressure sensor</td>
<td>1 Gyroscope and 1 low-g accelerometer for Roll-over sensing</td>
<td>5 Accelerometers for active suspension</td>
</tr>
<tr>
<td>1 Manifold air pressure sensor</td>
<td>1 Accelerometer for airbag ECU (Structure-borne sound sensor)</td>
<td>1 Pressure sensor, 1 humidity sensor for air conditioning</td>
</tr>
<tr>
<td>1 Oil pressure sensor</td>
<td>4 Accelerometers and 2 pressure sensors for peripheral airbag sensors</td>
<td>2 gas sensors for air quality</td>
</tr>
<tr>
<td>1 Common rail high pressure sensor</td>
<td>2 Pressure sensors for pedestrian safety</td>
<td>1 Angular rate sensor and 1 acceleration sensor for navigation systems</td>
</tr>
<tr>
<td>1 Tank pressure sensor [Tank pressure]</td>
<td>1 Gyroscope, 1 low-g accelerometer and 1 high pressure sensor for ESP / ACC</td>
<td>3 Microphones for speech recognition</td>
</tr>
<tr>
<td>1 Pressure sensor [Start/stop function]</td>
<td>1 Gyroscope for active steering</td>
<td>1 Bolometer Array for night vision</td>
</tr>
<tr>
<td>2 Accelerometers for active engine mounts</td>
<td>1 Accelerometer for eCall</td>
<td>1 Accelerometer for car alarm</td>
</tr>
<tr>
<td>1 Pressure sensor for particulate filter</td>
<td>4 Tire Pressure sensors and 4 accels</td>
<td>(Seldom: 16 Pressure sensors (up to 8 pressure sensors per seat)</td>
</tr>
</tbody>
</table>

Automotive Electronics | AE/PRM-S | 2019-06-12

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# MEMS Sensors

## Automotive Product Portfolio

<table>
<thead>
<tr>
<th>Acceleration sensors</th>
<th>Angular rate sensors</th>
<th>Inertial sensors</th>
<th>Pressure sensors</th>
<th>Mass flow sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acceleration sensors</strong> for occupant protection</td>
<td><strong>Rollover sensors</strong> for occupant protection</td>
<td><strong>Combined inertial sensors</strong> (accelerometer and yaw rate) for VDC, RSC and RoSe</td>
<td><strong>Low pressure sensors</strong> for engine control</td>
<td><strong>Mass flow sensors</strong> for engine management</td>
</tr>
<tr>
<td><strong>Low-g acceleration sensors</strong> for VDC, RoSe and active suspension</td>
<td><strong>Yaw rate sensors</strong> for VDC</td>
<td><strong>6 axis combined inertial sensor</strong> (accelerometer and yaw rate) for navigation and non-safety applications</td>
<td><strong>Mid-pressure sensors</strong> for transmission control</td>
<td></td>
</tr>
<tr>
<td><strong>Low-g acceleration sensor (3-axis)</strong> for navigation / non-safety funct.</td>
<td><strong>Angular rate sensor (3-axis)</strong> for navigation / non-safety funct.</td>
<td><strong>Pressure sensors</strong> for occupant protection</td>
<td><strong>Pressure sensors</strong> for engine and brake systems</td>
<td></td>
</tr>
</tbody>
</table>
MEMS – a success story
From first cars to an indispensable element in our lives

- 1990
- 2000
- 2010
- 2020

1st wave
2nd wave
3rd wave

Consumer Electronics
Internet of Things (IoT)
Market overview

Internet of Things – Connected smart systems and sensors

- Multiple (MEMS) sensors
- Wireless connectivity
- Microcontroller
- Embedded software
- (Ultra low) Power Management
- Small form factor

Internet of Things

Wireless connected smart sensors and actuators - Enabler for the IoT
Market overview

Total MEMS market

MEMS is a rapidly growing market - driven mainly by CE and Automotive applications

Source: Yole, Status of the MEMS Industry 2018
Market overview
Automotive MEMS market

MEMS Sensors for automotive are a > 3 billion US$ market

Source: IHS – Automotive MEMS market tracker – H1 2019
Market overview

TOP 10 MEMS automotive suppliers

Bosch is world’s largest MEMS supplier for automotive applications

Source: IHS MEMS Market Tracker Automotive 2019-H1
Market overview

TOP MEMS suppliers by revenue 2017

Bosch is world’s largest MEMS sensor supplier

Source: YOLE, Status of the MEMS Industry 2018
MEMS @ Bosch
Bosch – The MEMS pioneer

- Start of MEMS production in 1995
- More than 10 billion MEMS sensors produced
- More than 1000 MEMS patents
- 100% in-house – from MEMS design to MEMS manufacturing

Bosch - Decades of expertise in MEMS development and MEMS mass production
MEMS Sensors
Three pillars of MEMS

Automotive Electronics - AE
- MEMS for automotive applications
  - Accelerometers, Gyroscopes, Inertial sensors, Mass flow, and Pressure sensors

Bosch Sensortec - BST
- MEMS for consumer applications
  - Accelerometers, Gyroscopes, Inertial, Magnetic, Pressure and Environmental sensors

Bosch Connected Devices and Solutions - BCDS
- MEMS-based IoT sensor solutions
  - Wireless Sensor solutions for Telematics, Data logging, and Industrial IoT applications

Bosch - a global supplier of MEMS sensors for automotive, consumer and IoT markets
MEMS @ Bosch
From automotive to the internet of things

1995
First internal automotive MEMS business
1st high volume pressure sensor for power train application

1999
External automotive MEMS business
Distribution of Sensor via Product Team Sensors PT-S

2005
Foundation of CE Bosch Sensortec
Development and distribution of MEMS sensors for consumer markets

2009
Acquisition of Akustica
MEMS microphones for consumer markets

2013
Foundation of BCDS
Bosch Connected Devices and Solutions GmbH
MEMS products for I4.0 / Internet of Things
MEMS @ Bosch
Wafer fabs in Reutlingen

Employees
3674

Production area
34 300 sqm

Minifactories
Frontend: ASIC und Sensor Waferfab
Backend: Wafer Test, Sensor Montage (Assembly)

Products
IC, power S/C (chip and packaged), sensors (packaged, customer specific mold package)

150 mm module
- 4 100 sqm
- 1 500 wafer starts/day
- Technologies:
  - BCD1, 2, 3, 3s, 4, 4s
  - CMOS, Bipolar, PSC bipolar, MOS
  - Pressure sensors
  - Inertial sensors
  - Process: ≥ 0.5 µm

200 mm module
- 4 600 sqm
- 1000 wafer starts/day
- Technologies:
  - BCD4, 4s, 6, 6sCu
  - Advanced CMOS, HVCMOS
  - Pressure sensors
  - Inertial sensors
  - Process ≥ 0.18 µm
MEMS @ Bosch
Development and production at one location

Reutlingen site, Germany

Sensor development
MEMS sensor production
Semiconductor development
150/200mm Wafer testing
150mm Wafer production
200mm Wafer production

MEMS and semiconductor development, production and testing on one site
MEMS market overview
From laboratory to mass production

- **1967**: First MEMS sensors (Kulite, Stanford, Honeywell)
- **1970**: MEMS scanning Mirror (K. Petersen, IBM)
- **1980**: Development of inkjet printers (HP (Thinkjet), Canon (Bubble Jet))
- **1990**: Micromachine silicon tuning-fork gyroscope (Draper Labs)
- **1991**: Resonant-gate transistor with metal-beam micromachining
- **1993**: Micromachine silicon tuning-fork gyroscope (Draper Labs)
- **1994**: New DRIE-process ("Bosch process")
- **1998**: Micromachine silicon tuning-fork gyroscope (Draper Labs)
- **2000**: Development of "Digital Light Processing" technology (TI)
- **2003**: Fully-integrated single-chip Accelerometer (Analog Devices)
- **2007**: Wire-bonding of MEMS sensors (b吕chel + Kistiakowsky) (Bosch)
- **2008**: Mass production of Automotive gyroscope (Bosch)
- **2008**: First company with over 1 billion produced sensors (Bosch)
- **2009**: APSM technology for pressure sensors (Advanced porous silicon membrane (Bosch))
- **2010**: Tire-pressure sensor (Motorola)
MEMS market overview

Milestones MEMS sensors at Bosch (1/2)

- Air mass flow sensor
- 1st gen. Peripheral acceleration
- 1st gen. Airbag acceleration sensor
- 3rd gen. Peripheral acceleration sensor
- 2nd gen. Airbag acceleration sensor
- 2nd gen. Barometric pressure sensor
- Foundation of Bosch Sensortec: MEMS for Consumer Electronics
- 4 x 4mm² CE triax acceleration sensor
- 2nd gen. ESP gyroscope
- 3 x 3 mm² CE triax acceleration sensor
- Inventor of the year 2007 (Bosch Process)

1995
- First volume MEMS-product: 1st gen. Pressure sensor
- iBolt™ occupant weight sensor
- Digital pressure sensor for CE applications

1996/97
- 1st gen. Barometric pressure sensor
- 2nd gen. High pressure sensor
- 4th gen. Peripheral acceleration sensor
- 2nd gen. Peripheral pressure sensor

1998/99
- 1st gen. ESP gyroscope
- 1st gen. Rollover gyroscope
- 2nd gen. ESP gyroscope

2000

2001

2002

2003/04

2005

2006

2007
MEMS market overview
Milestones MEMS sensors at Bosch (2/2)

2008
- 5th gen. Peripheral acceleration sensor
- Deutscher Zukunftspreis 2008 for Smart Sensors
- 1st gen. ESPi sensor

2009
- 1st inertial sensor in mold package
- 1st 2 x 2mm² CE triax
- 1st gen. mid pressure sensor for transmissions
- 3rd gen. high pressure sensors

2010
- 1st CE gyroscope
- 1st CE inertial sensor
- 2nd gen. ESPi sensor
- 1st multi-chip MEMS microphone

2011
- 5bn MEMS sensors
- 1st ESP inertial sensor in BGA package
- Next gen. high pressure sensors
- 1st CE inertial sensor sub 1mA in 2.5 x 3 mm²

2012
- 2nd gen. Peripheral pressure sensor
- 2nd, gen. Rollover gyroscope
- Acquisition of Akustica Inc.

2013
- 1st digital barometric pressure sensor for AUT
- Smallest integrated digital MEMS microphone
- 1st digital CE compass with "FlipCore" technology

2014
- 2nd gen. CE compass
- Smallest CE 3-axis MEMS sensor
- 1st CE 9-axis sensor

2015
- 1st CE smart sensor hubs
- 6th gen. Peripheral acceleration sensors
- World’s 1st indoor air quality sensor

2016
- World’s smallest AUT triax accel. (2 x 2mm²)

2017
- 3rd gen. ESPi sensor

2018
- 2nd gen mid pressure sensor
THANK YOU!