New Sensors for New Applications

Taipei, 4th of September 2014

百里博 / Leopold Beer Regional President Asia Pacific
MEMS Sensors for New Applications

Agenda

- Industry state of the art solutions - today’s technologies
- Industry evolution and requirements - tomorrow’s requirements
- Enabling new markets and applications

Generic industry view based on Bosch Sensortec examples
MEMS Sensors for New Applications

Bosch – the leading MEMS sensor supplier

Out of one hand MEMS sensors, actuators and solutions

<table>
<thead>
<tr>
<th>Bosch Sensortec</th>
<th>Akustica</th>
<th>Bosch Connected Devices &amp; Solutions</th>
<th>Automotive Electronics</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE</td>
<td>CE</td>
<td>CE &amp; Industrial</td>
<td>Automotive</td>
</tr>
<tr>
<td>➤ Accelerometers</td>
<td>➤ MEMS microphones</td>
<td>➤ Smart sensor/ actuator nodes</td>
<td>➤ Accelerometers</td>
</tr>
<tr>
<td>➤ Geomagnetic sensors</td>
<td></td>
<td>➤ Embedded SW &amp; algorithms</td>
<td>➤ Angular rate</td>
</tr>
<tr>
<td>➤ Gyroscopes</td>
<td></td>
<td>➤ Customized IoT sensor &amp; actuator solutions</td>
<td>➤ Pressure sensors</td>
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<tr>
<td>➤ Pressure sensors</td>
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<td></td>
<td>➤ Mass flow sensors</td>
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<tr>
<td>➤ Humidity sensors</td>
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<tr>
<td>➤ Combo sensors</td>
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<td></td>
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<tr>
<td>➤ ASSNs</td>
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</table>
Wearable MEMS Sensor requirements

Bosch MEMS Sensor Shipments (mill pcs.)
MEMS is microscopic fascination

“MEMS” = “Micro-Electro-Mechanical System”

- MEMS are miniature systems which usually 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 into one unit, e.g. into an LGA package.
Bosch Sensortec evolves with the market

- Technology Focus
  - Application focus
  - Technology focus

- Technology broad-liner
  - Application focus
  - Broad technology portfolio

- Industry broad-liner
  - Broad application portfolio
  - Broad technology portfolio

Year:
- 2006
- 2011
- 2014
- 2016
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New applications...with new technologies

**Multitude** of **technologies** (Inertial, GeoMagnetic, Environmental, Acoustic...)

Implement **Application specific** (Smartphone, Wearable, Tablets...)

**Solutions** (Integrating sensors, μC and application specific software)

Broad Technology Portfolio  &  Broad Application Know-How
# MEMS Sensors for New Applications

## State of the art Technology portfolio

<table>
<thead>
<tr>
<th>Inertial</th>
<th>Geomagnetic</th>
<th>Environmental</th>
<th>Sensor Clusters</th>
<th>Microphones</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Accelerometer" /></td>
<td><img src="image2" alt="eCompass" /></td>
<td><img src="image3" alt="Barometric Pressure" /></td>
<td><img src="image4" alt="Sensor Hubs" /></td>
<td><img src="image5" alt="Analog and digital MEMS microphones" /></td>
</tr>
<tr>
<td>Gyroscope</td>
<td>GeoMag</td>
<td>Environmental Temperature</td>
<td>ASSN</td>
<td>(Akustica)</td>
</tr>
<tr>
<td>IMU</td>
<td>Magnetic Gyro</td>
<td>Environmental Humidity</td>
<td>SIP &amp; SOC</td>
<td>High quality voice input for mobile devices</td>
</tr>
<tr>
<td>9 Axes</td>
<td></td>
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</tbody>
</table>

Sensor data-fusion software ties everything together
## Cross application product portfolio

<table>
<thead>
<tr>
<th>3-axis</th>
<th>6-axis</th>
<th>6+3-axis</th>
<th>9-axis+3</th>
<th>PTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMM150</td>
<td>BMC150</td>
<td>BMC+BMG</td>
<td>BME280</td>
<td></td>
</tr>
<tr>
<td>BMA355</td>
<td>BMI058</td>
<td>BMI+MIM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMG160</td>
<td></td>
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</table>

**FusionLib:**
- BSX 3.0

**BSX**
- BSX*3.5
- BSF in BNO
- BSF in BNX (for ASSN**)

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**Different applications require different solutions**
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New markets segmenting out of smartphone

Higher Integrated Functionality

Wearable Devices
(integrating sensors)

IoT Nodes
(multiple sensors, μC and RF link)

Lower Power Budget

IoT Tags
(Sensor & RF-Link)

Higher Power Budget

Smart Switches
(event type sensors)

Smart Phone Sensors

Lower Integrated Functionality
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Top level requirements

Wearable Devices
- Standard bus interfaces
- Integrated data processing
- Sensor integrated power management
- Combo sensors

IoT Nodes
- Wireless Interfaces (TCP/IP capable)
- Programmable & Reconfigurable (OTA)
- System power management
- Combo sensors

Smart Switches
- Interrupt engine & interface
- Integrated data processing
- Sensor integrated power management
- One parameter sensors

IoT Tags
- Wireless Interfaces (TCP/IP capable)
- Configurable (State Machine)
- System power management
- One or multiple parameter sensors

Higher Integrated Functionality

Lower Power Budget
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New Components...by Integration

Wearable Devices

Smart Switches

Higher Integrated Functionality

IoT Tags

IoT Nodes

Lower Power Budget

Higher Power Budget

Lower Integrated Functionality
Solution Drive: Software support models

Ported Solutions
- BSX ported to partner μC architecture
- As of today BSX has been ported to > 4 3-rd party μC

AP Integrated
- Generic BSX * libraries
- Customer specific adaptations are possible

3-rd Party Solutions
- Partner integrates SDF** & Bosch Sensortec supports with drivers
- BNO available in “non pre-programmed” version

Component Integrated
- BNO integrates BSX for Sensor Hub applications
- BNO integrates application specific SDF** for ASSN***

* Bosch Sensortec Sensor Data Fusion
** Sensor Data Fusion
*** Application specific sensor node
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Shrinking in Size: BMA355 disruption

With a size of only $1.4 \text{mm}^3 \ (1.2 \times 1.5 \times 0.8 \text{mm})$, the BMA355 is the smallest MEMS accelerometer on the market and features **60% volume reduction** compared to state of the art 2x2x0.9mm MEMS accelerometers.

- This size reduction has been made possible by the use of a Through-Silicon Vias (TSVs) in the ASIC enabling a **WLCSP package** where all the manufacturing steps are realized at the wafer-level.

Images and text courtesy of System Plus Consulting
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Increasing level of integration: BNO055 platform

- Quaternion
- Linear Acceleration
- Rotation
- Gravity
- Robust Heading
- ...

User Motion

Windows 8.1 compliant
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The ASSN* Platform Concept

**Sensor HUB** (including BSX)
- Smartphone
- Tablets
- Laptops

**ASSN** (including BSF)
- UI /SWatches / RemCon / gaming
- Sports devices / activity monitoring
- Inertial tracker (navigation)

**Generic Sensor Node** (programmable)
- Wearable devices
- Security systems...
- IoT Nodes..

* Application specific sensor node
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Integrated Environmental sensor: BME280

- **Pressure, temperature and humidity**

- Small Size: 2.5 x 2.5 mm²

- Low power: 8 µA

- High accuracy @ Low latency
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Extreme Low Power IMU: BMI160

- **Lowest Power in the Market**
  - 950µA in full operation (1.8V)
  - 3 x lower than nearest competitor

- **Smallest Package**
  - 2.5 x 3.0 x 0.8 mm
  - 16 % smaller footprint than 3x3

- **Integrated Functionality**
  - Activity / Inactivity Interrupt
  - Low power Step detector & Step counter
  - Position change & tap sensing interrupts
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Pioneering a new class of devices

BNO070, based on 9-axis BNO055, incorporates Hillcrest’s SH-1 software optimized for head-mounted displays (HMDs)

<table>
<thead>
<tr>
<th>BNO070</th>
<th>Technical data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>5.2 x 3.8 x 1.1 mm³</td>
</tr>
<tr>
<td>Update Rate</td>
<td>≤250Hz</td>
</tr>
</tbody>
</table>
| Static                  | Accuracy: 1.5°
|                         | Heading: 1.0°
|                         | Non-Heading: 1.0°                                   |
| Dynamic                 | Accuracy: 1.5°
|                         | Heading: 1.0°
|                         | Non-Heading: 1.0°                                   |

Absolute orientation solution for head mounted displays (HMD)
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Main Take-Away

Key Success factor is to address the full range of components at all integration levels as solution approaches for consumer electronics Applications.

Key requirements are

Technology Mastering -> to manage a broad technology portfolio

Application Know-How -> to develop the right solutions

HW-SW co-design -> design for power & cost efficiency
ABB, Bosch, Cisco, and LG aim to set up a consortium to provide a software platform for smart homes. The companies have now signed a memorandum of understanding to this effect. The plan is subject to approval by the antitrust authorities.
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Thank You, Questions?

Bosch Sensortec

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