Smart System Design: Industrial Challenges and Perspectives

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SMAC (FP7 ICT): Challenges and Goals

Integrating digital IPs and “More than Moore” technologies to move Multi-Package on Board to Multi-Chip in Package

Achievable via:
- Smallest scale
- Energy-savings
- Low cost

Need of a mainstream design methodology
- automated, integrated, reliable and repeatable

SMAC Platform: will build a co-design and integration environment to allow multi-physics, multi-layer, multi-scale and multi-domain Smart System simulation and optimization

- Harvesting Device (PV, Piezo, etc)
- Power Management
- Energy Storage: Supercap, Flexible Batteries
- Wireless Transmission: RF low power, ZigBee, ...
- Sensors
- Analog Front End, Back End
- Low Power Digital Processing
- Power Actuators: SiC, GaN, Power Mosfet, IGBT

Highly compact ...

Ultra low power
The magic circle of Smart Systems’ value-chain

- Manufacturing value-chain of smart systems enjoys a virtuous escalation among the process development and product deployment (macro system).

- This circle is a key differentiator and a strategic asset of Smart Systems industry

  - Tech PUSH: Manufacturing Capacity
    - MEMS
    - Smart power
    - Etherogeneus integration

  - Market PULL: Key driver applications:
    - Energy efficiency, smart energy grid
    - Automotive
    - Home and fab automation, sustainable transport
    - Healthcare (MNBS)
Enabling Technologies for “More than Moore”

“More than Moore” is:
• Silicon technology scaling
• New materials and processing
• Application driven (or drives new applications)
• Many more Functions

ST Main Technologies

• System-on-Chip

• Ultra low power technologies

• Advanced CMOS, BCD technologies

• Harvesting & Thin Batteries

• SiC & GaN new materials

• MEMS & Smart Sensors technologies

• Advanced packaging & System-in-Package

• 3D Heterogeneous Integration/ TSV

• Flexible ICs
MEMS in ST: A Success Story

- **Inkjet**
- **Accelerometers**
- **Gyrosopes**
- **9-Axis Modules & Sensor Fusion SW, Dual Core Gyroscope**
- **Piezo, Pressure, Magnetic, micro-mirrors for pico-beam**

Timeline:
- **90’s**
- **2005**
- **2010**
- **2012**
- **2013**

Augmented Content
- **Smart Phones & Tablets**
- **PCs, Gaming consoles**
- **Printers**

Augmented Content smart phones, gaming consoles, and printers.
Top MEMS Manufacturers for Consumer and Mobile

As a pioneer in MEMS technology, ST is leading the MEMS Consumer and Mobile Market since 2008, with Market share > 50% for Motion Sensors

Leadership in Motion MEMS Market

Motion MEMS Market in 2015

Sources: iSuppli January 2012, iSuppli H1 2011
Growing Faster than Market: MEMS in ST
2011 Key Facts

ST’s MEMS revenue

$30M

2006

$650M

2011

Growth > x20 in 5 Years

• ST #1 in MEMS Motion Sensors for consumer electronics and mobile handset market
• ST #1 in Accelerometers, Market Share ~50%

GYROSCOPE MARKET SHARE

• ST #1 in Gyroscope
• Market Share ~60% (in only two years)

Sources: IHS iSuppli January 2012, Yole Development
• MEMS takes advantage of the electrical and mechanical properties of silicon:
  
  - an **Advanced Analog Chip** with embedded smart functionalities
  
  - Micro-scale **Transducer** realized through a specific process called **Micro-Machining**

• Dedicated **package** and **calibration** features
3 Axes Gyroscope

Leadership through Innovation & time2market: > 650 patents

F_{Coriolis} = -2m\Omega_z \wedge \mathbf{v}

\[ \Omega_z \]

\[ \mathbf{v} \]

\[ \mathbf{x} \]
Accelerometer and Gyroscope: System Approach

Stacked Configuration

Accelerometer MEMS

\[ A \rightarrow mg \]

\[ \Delta C \]

ASIC

\[ mV \text{ digits} \]

Analog or Digital Output

Gyroscope MEMS

\[ \Omega \rightarrow \]

\[ \Delta C \]

ASIC

\[ mV \text{ digits} \]

Analog or Digital Output
The iNEMO platform enables New Applications through sensor fusion

- MEMS accelerometer
- MEMS gyroscopes
- MEMS magnetometer

Sensor fusion
- AHRS orientation algorithm

Precision space orientation
- Roll
- Pitch
- Yaw

Enabling new applications

Portable navigation devices
Service robots
Unmanned aerial toy
Automotive
Advanced video games

Note: AHRS = Attitude Heading Reference System
…Enabling New Applications & Services

- Remote Monitoring
- Navigation & LBS
- Image Stabilization
- Augmented Reality
- Location Based Services (LBS)
- 3-Dim Tagging
- Indoor Navigation and Dead Reckoning
- Fitness/Wellness and In-House Tele-health
Dual-Core 3x Digital Gyroscope

• Targeting User Interface and Optical Image Stabilization (OIS)
• High full-scale required for User Interface (UI)
• Ultra low-noise & very high speed required for Optical Image Stabilization (OIS)
• Smart power management and independent power supply

2.5x noise reduction

10X noise reduction

10X speed increase
A look to the Inside…

• Key Parameters
  • Low Current: 20 μA
  • High Resolution: 12-bit
  • Low Noise: 2 m gauss RMS

...and from the Outside

Chinese characters: 地理定位器

English translation: Geo-Magnetic Sensor

Chinese characters: 加速度计

English translation: Accelerometer

Chinese characters: LSM303DLHC digital compass

English translation: LSM303DLHC digital compass

Chinese characters: 3 mm

English translation: 3 mm

Chinese characters: 5 mm

English translation: 5 mm

Chinese characters: 1 mm

English translation: 1 mm
Altimeter/Barometer Enables 3D Indoor Positioning and Enhanced GPS in Portable Devices

World’s Smallest Pressure Sensor

- **Applications:**
  - altimeter, barometer and motion sensors for portable devices, smartphone, indoor and outdoor navigation systems

- **Products features:**
  - 200 to 1260 mbar absolute pressure range
  - 20 cm altitude resolution
  - Embedded temperature compensation
  - Embedded 16-bit ADC
  - SPI (Serial Peripheral Interface) and I2C Interfaces
  - Supply voltage: 1.8 to 3.8 V
  - High shock resilience: 10 Kg

8 m = 1 mBar

ST is the only supplier of full solution MEMS sensors for geo-localization:
Accelerometer + Gyroscope + Magnetometer + Pressure Sensors
The new Entry: MEMS Microphones

ST’s PATENTED technology allows to place MEMS sensor adjacent to the inlet in both top and bottom port microphones, achieving superior performance.

Dual stack-die architecture

• Application Segments:
  • Mobile phone
  • Digital camera/camcorder
  • Laptop PC
  • Gaming

… Analog or Digital microphone
ST invests in high-growth areas: 3D video goggles

- ST has a strategic agreement, with MicroOLED, a Grenoble-based company developing and commercializing state-of-the-art organic light-emitting diodes (OLEDs) with exceptionally high resolution and extremely low power consumption,
ST acquires bTendo technology for pico-projectors in smart consumer devices

- bTendo, an Israeli-based company with innovative projection technology targeted at smartphones and other portable consumer devices.

- Huge emerging market of embedded projectors in next-generation portable consumer devices.

- The market for pico-projectors is expected to expand to 58 M units in 2015, up from about 3 million units shipped in 2011 (according to IHS iSuppli). CAGR > 80%.

- Combining ST technical expertise with bTendo’s Scanning Laser Projection engine, enable us to meet the demands of the emerging market of embedded projectors while preparing to open up new markets.
MEMS in Automotive

- Navigation assistance
- Anti-theft systems
- Crash recording

Emerging applications

Passive safety applications
- Satellite Airbags
- Frontal Airbags

Active safety applications
- ESC (electronic stability control)
- Post-crash door unlock system
MEMS in Automotive: Passive Safety

- **Standard Airbag Control Unit**
  Accelerometers or impacts detection

- **Advanced Airbag Control Unit**
  With Roll-Over Detection for side Airbag
  - 1-Axis Angular Rate Sensor (x)
  - 2-Axis accelerometer (y,z)

- Accelerometer Automotive grade
ESC (Electronic Stability Control)
Oversteering / Understeering prevention
The rotation information is used to detect that the vehicle is about to travel in a direction different from the one indicated by the steering wheel position.
Smart Systems Roadmap

1\textsuperscript{st} Generation

- **Integrated & Miniaturized**
  - Systems with advanced functionality

2\textsuperscript{nd} Generation

- **Predictive & Reactive**
  - Smart Systems matching harsh environments and equipped with advanced energy management capabilities.

3\textsuperscript{rd} Generation

- **Autonomous**
  - Self aware, autonomous systems interfacing physical w/ virtual world, adaptive to environment, ubiquitously connected, with cognitive abilities

- **Driver Status Monitoring**
- **Piezo Injection Valve**

- **Smart Pill**
- **Smart Implants**
- **DNA Lab on Chip**
- **fuel cells**

- **Autonomous (Bio)-Robot**
- **Swarming Agent**
- **Internet of Things**
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