InvenSense: MEMS Start-Up to Market Leader

Joe Seeger
September 15, 2010

Agenda

- Introduction & History
- Motion Processing
- MEMS Startup Challenges
- InvenSense Solutions
- Summary & Conclusions
InvenSense Overview

<table>
<thead>
<tr>
<th>Status</th>
<th>• Funded in 2004, nearly 200 employees today</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market</td>
<td>• Consumer Electronics</td>
</tr>
<tr>
<td>Customer</td>
<td>• Major consumer electronic OEM and ODM companies</td>
</tr>
<tr>
<td>Solution</td>
<td>• New generation of motion based interfaces</td>
</tr>
<tr>
<td>Technology</td>
<td>• Nasiri-Fabrication and MotionProcessing Platforms</td>
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<tr>
<td>Manufacturing</td>
<td>• Fabless CMOS &amp; MEMS, nearly 100MU shipped</td>
</tr>
<tr>
<td>Patents</td>
<td>• 56 filed and issued with many core IP</td>
</tr>
</tbody>
</table>

InvenSense Precursors, 2003

*S. Bhave, J. Seeger, X. Jiang, B. Boser, R. Howe, J. Yasaitis, Transducers 2003*

*S. Nasiri, Transparent Networks Inc.*
MEMS Gyroscope Market, 2003

Historical Perspective
- First demonstrated by Draper Labs in early 1990
- Bosch commercialized it for automotive VSC in 1997

Key Market Drivers in 2003 for MEMS Gyro
- >10 MEMS gyro companies at various stages, all for automotive
- All single axis, mostly Z-axis at around $15/axis
- Bulky, high current, and costly for consumer products

Opportunity: Low Cost Consumer Grade MEMS Gyros
- Driven by DSC/DVC image quality, all Japanese companies
- Single axis Piezo gyros ~$3.5/axis; Murata, NEC and Fujitsu
- Key issues: Performance, Bulky, Fragile and need for external electronics

Consumer Grade MEMS Gyro
- MEMS gyros were thought as unfeasible to get below $3/axis

InvenSense Prototype Gyroscope
- MEMS Wafer
- Integrated IC
- InvenSense Prototype Gyroscope
State-of-the-Art Solutions

- 2004 (inception)
- 2006
- 2008
- 2009
- 2010
- 2011

- 1st generation X/Y gyro 6x6x1.4mm
- 2nd generation X/Y Gyro 4x5x1.2mm
- X/Z Gyro 4x5x1.2mm
- MPU-3000 with X/Y/Z Gyro 4x4x0.9mm

Motion Processing

- Image Stabilization
- Gaming
- TV Remote

What is Motion Processing?

Motion Application Software (MAS)
Motion Processing Library (MPL)
Digital Motion Processor (DMP)
Motion Algorithms
Sensor Fusion
Gyre
Accel
Analog to Digital
Motion Sensors
Compass
Others

3rd Party Applications

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MotionProcessing: “Interface to Digital World”

Consumer Market Dynamics

Highly Competitive and Feature Driven

- Need for product differentiation and new features
- Adoption by thought leaders and acceptance by customers
- Must solve a real need to get traction with customers

Very Demanding for Size, Cost and Volume

- Constant and relentless drive to lower prices
- Unpredictable demands and shipment schedules
- Actively encourages multiple suppliers and fierce competition
- Need for complete solutions and thorough customer education

Late Adopter of New Technologies

- What are the real killer applications?
- Skeptical of consumer behavior and willingness to change
- Market is driven by only a few thought leaders
- Need for delivering total solution and lots of support
MEMS Startup Challenges

**Market Knowledge**
- Understand market need and application

**MEMS Production**
- Address Fabrication, Packaging, Test, & Capacity challenges
- High-volume MEMS production experience?

**Engineering & MEMS Development**
- Address MEMS simulation, IC design specific to MEMS
- MEMS is one component of total system
- Address cost, yield, performance and develop new products
- MEMS design knowledge & commercial product experience?

**Disruptive Technology**
- Need some "unfair" advantage to compete against established companies
- Is it a Feature, Product, or Platform?
Challenges With Low Cost MEMS

Presented by Leading MEMS Company in 2005

- **Packaging**
  - Approximately 33% of the cost
  - Most of the reliability issues
  - Difficult to standardize

- **Testing**
  - Approximately 33% of the cost
  - Test tools needed for characterization
  - Special tools needed
  - Requires mechanical and electrical design

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Nasiri-Fabrication Platform

**MEMS Substrate**
- Si Wafer 1
- Backside Marks (M1)
- Si Cavity etch (M2)
- Fusion Bond Si Wafer 2
- Grind and Polish
- Hermetic seal ring and Interconnect (M3)
- Ge based coating (M4)
- Structure layer etch (M5)

**CMOS Wafer**
- Cavity Etch (M6)

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Wafer-Scale Integration

Inherent Benefits of Nasiri Fabrication

- **Bulk Silicon Fabrication**
  - Most suitable for inertial sensors
  - Using off-the-shelf equipment
  - CMOS compatible process allows easy porting

- **Wafer Level Eutectic Bonding**
  - Enables wafer-level integrations with CMOS
  - Provides wafer level reliable hermetic vacuum seals
  - Metallic eutectic bonding, no need for getter
  - ~50% die size w/ small seal rings and interconnects,

- **Wafer Level Testing**
  - Lowest cost semiconductor level testing
  - Timely feedback for process and quality monitors

- **Portable and Versatile**
  - Easily ported to multiple MEMS or CMOS foundries
  - Suitable for Gyro, Accel, Pressure, Resonators, more
Opportunity in Packaging

Costly pick and place
Costly ceramic package
Costly test and cal

Inherent Cost Benefit

CMOS-MEMS
Wafer Sort Testing
Low Cost QFN Assy

Semiconductor Like Process Flow

<table>
<thead>
<tr>
<th>CMOS-MEMS</th>
<th>Wafer Sort</th>
<th>Packaging</th>
<th>FT &amp; Ship</th>
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MotionProcessing™ Technology

MEMS is one component in the system...

...but tightly coupled to CMOS design
MEMS & IC layouts are coupled too

MEMS Requires IC-like Design Flow
Development Achievements

<table>
<thead>
<tr>
<th>Year</th>
<th>Die Size</th>
<th>CMOS</th>
<th>Output</th>
<th>Power</th>
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</thead>
<tbody>
<tr>
<td>2006</td>
<td>12.2mm²</td>
<td>0.5µm</td>
<td>Analog</td>
<td>27mW</td>
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<tr>
<td>2008</td>
<td>7.4mm²</td>
<td>0.35µm</td>
<td>Analog</td>
<td>20mW</td>
</tr>
<tr>
<td>2009</td>
<td>7.4mm²</td>
<td>0.35µm</td>
<td>Analog</td>
<td>20mW</td>
</tr>
<tr>
<td>2010</td>
<td>6.7mm²</td>
<td>0.18µm</td>
<td>Digital</td>
<td>14mW</td>
</tr>
</tbody>
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Lessons Learned...

- **Go for Breakthrough Solutions**
  - Must have some real competitive edge to succeed
  - Aim at much lower cost than existing solutions (2X to 3X)

- **Develop Multiple Foundries**
  - Develop proprietary process fabrication IP that can scale
  - Consider 2nd source foundries early on

- **Design for Low Cost Solution**
  - Stay with standard packages and test equipment
  - Invest in your in-house testing and calibration facilities
In Summary...

MEMS Motion Processing Market: High Growth Opportunity
- Very large and rapidly growing market
- Requires complete solution to help customers with time to market

Challenges with the Consumer Market
- High performance at low cost with rapid production ramp
- Adoption is dependent on few thought leaders

High Volume MEMS Commercialization
- Has taken nearly 20 years for MEMS gyro to meet consumer market needs
- Had to provide over 20X reduction in price, and size

Development of Low Cost and High Volume MEMS Products
- Fabless MEMS is the only way for new start up to offer new MEMS products
- Must follow fabless semiconductor model as closely as possible
- CMOS-MEMS and wafer level packaging and testing is the key

Thank you