

Technology Trends for Inertial MEMS

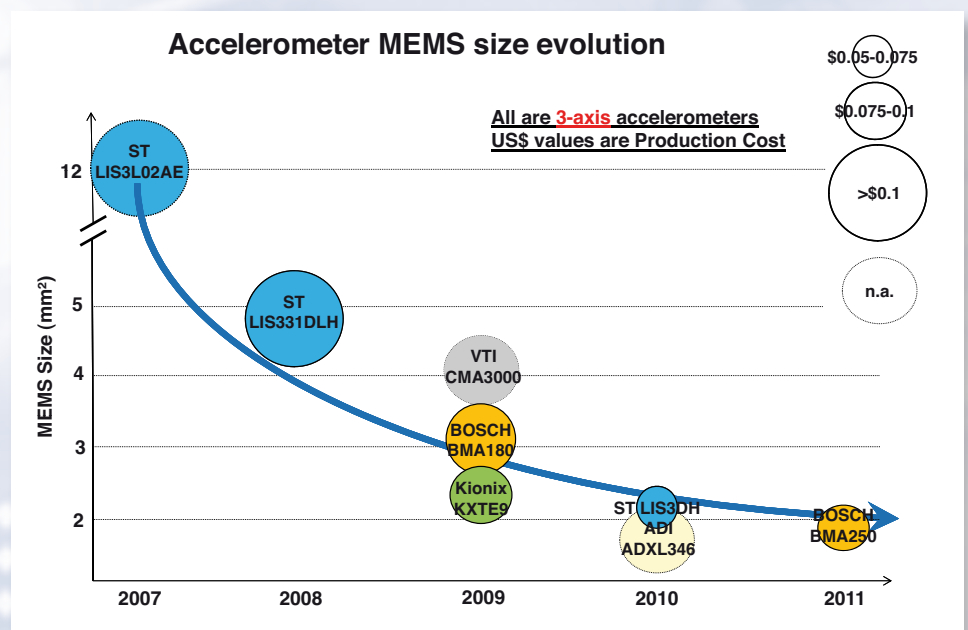
MARKET & TECHNOLOGY REPORT – JANUARY 2012

Evolutions of front-end, assembly & test based on the teardown of 23 MEMS (accelerometers, gyroscopes, magnetometers & combos)

MAJOR MARKET DRIVERS & TECHNICAL ANSWERS IN INERTIAL MEMS & MAGNETOMETERS

Over the last 3 years, inertial MEMS & magnetometers have been subject to dramatic market & technological evolutions. This has been driven by a large increase of the consumer market: mobile phones and tablets for accelerometers; gaming for gyros; mobile phones for magnetometers.

Along with "stand-alone" MEMS devices, inertial combo sensors, a combination of several inertial sensors into a single package, are also coming. Main applications are consumer (e.g. accelerometer with magnetometer or accelerometer with gyro) and automotive for ESC and rollover functions first.



MEMS accelerometer die size evolution

Inertial MEMS & magnetometers are today driven by 4 major market trends:

1. Future generation of sensors will deliver functions and will become "solutions"
2. Fusion of sensors (combining data from different sensors) is starting to be widely used
3. New architectures are developed
4. Price pressure is still very strong (5% drop per quarter for consumer applications).

On the technical side, form factor is ever decreasing with reduced footprint and thickness. And power consumption has been reduced to a few microA while performances are still increasing.

The most successful type for inertial MEMS is based on capacitive transduction. Reasons are simplicity of the sensor element, no requirement for exotic materials, low power consumption and good stability over temperature. But will comb-drive architecture for accelerometers continue to be the main detection principle as MEMS die size keeps shrinking?

Regarding gyroscopes, most are falling into the categories of tuning vibrating fork/plate (STM, Bosch) or vibrating shells (Silicon Sensing Systems). This very common design gives ease of fabrication and possible integration in standard IC manufacturing industry.

For magnetometers, Hall Effect has been the dominant technology for a long time, but today it is changing as Magneto Impedance, Giant Magneto Resistance and Anisotropic Magneto Resistance are used. A new approach, Lorentz effect based on MEMS technology, is currently in R&D (VTT and others). This could bring easier integration in MEMS combo sensors.

MEMS TESTING WILL HAVE TO EVOLVE

Testing has been also subject to strong evolution over the last years. For example, combo sensors will require new test solutions compared to "stand-alone" sensors. Beyond the usual wafer-level electrical test and package-level electrical and mechanical or functional testing, these sensor combos will need module level testing and calibration of the combined sensors. If they include an MCU in the package, the communication between the sensors and the MCU will also need to be tested. Solutions need to be cost effective with high throughput to test multiple axes of multiple devices, either in parallel or in separate modules, rather like separate chambers in IC equipment.

The world of MEMS testing has moved in the last several years from internal development at MEMS makers to co-development with test suppliers to commercial off-the-shelf equipment. So combo solutions that can test all axes of the module in a single tool for higher throughput will also likely be co-developed with the test equipment suppliers and available commercially. Assembly and test houses may also start to offer these test services on an outsource basis for fabless or fab-light MEMS makers. The Yole report will analyze the latest trends in MEMS testing.

	In-House solutions	Platforms for MEMS with cooperations	Standard off the shelf tools	Test houses to be involved
Test players	Panasonic Ideas for life	BOSCH multitest	SPEA	京元電子 THE TESTING INDUSTRY RESEARCHER
Technical evolution	Automotive driven	Consumer driven	Driven by combos	
Cost of test	Few \$100Ks/tool + high development time	\$270M	<ul style="list-style-type: none"> • Combo test • Smart sensor • Equipment cost 	<ul style="list-style-type: none"> • Throughput • Design for test • Standardization • Limit number of test
	2005	2010	2015	

Standardization in testing! Inertial MEMS testing matures to limit the increase in cost

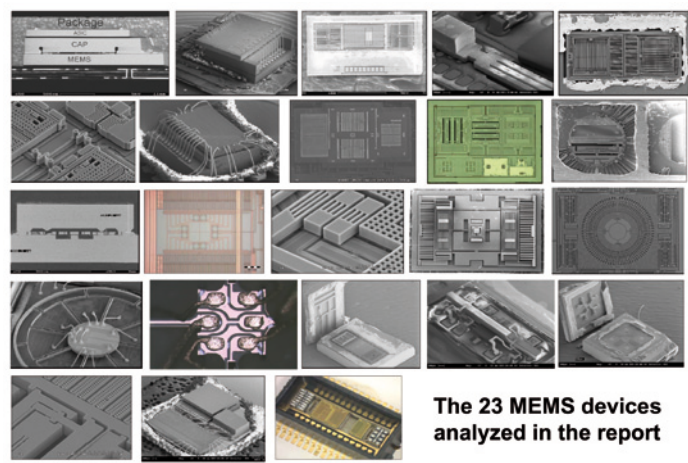
A COMPARATIVE ANALYSIS OF 23 MEMS DEVICES FROM 13 DIFFERENT MANUFACTURERS!

In order to understand the key evolutionary changes, **a total of 23 different MEMS devices (9 accelerometers, 10 gyros, 3 combos and 1 magnetometer) - mostly consumer MEMS - have been disassembled, analyzed and cost simulations have been constructed for MEMS, ASIC and Packaging/Test.** One of the key features of the reports is that ASICs have been analyzed as well. The MEMS have been analyzed and production costs have been simulated by System Plus Consulting, the reverse costing specialist company.

The teardown analysis results have been compared in terms of performance, total cost, MEMS size, ASIC lithography node, ASIC size, package size, year for market introduction.

From our analysis, we found there is a clear MEMS die size decrease over 2007-2011. For example, in 2008, the average size for an accelerometer (3-axis) was 4-5 mm². 3 years later, size is about 2 mm². ASIC size has been following the same trend with a lithography node in the range 0.18-0.35µ today. With latest ST announcement about the use of through silicon vias for inertial, we can expect even lower cost and size in the future.

The same analysis has been performed for gyros comps, combos and magnetometers.



KEYS FEATURES OF THE REPORT

The objectives of the reports are the following:

- **Provide an understanding of the market drivers for inertial MEMS**

- Consumer
- Automotive
- High-end

- **Give trends about packaging and tests strategies**

- **Provide in-depth analysis for 23 MEMS devices in terms of:**

- Production cost breakdown for MEMS, ASIC, Packaging & Test
- ASIC litho nodes

- Die & package size
- Package type
- Comparative analysis in terms of performance, production cost for MEMS, ASIC, sizes, year for market introduction.

- **For each device, photos are depicting:**

- MEMS close-up structure
- MEMS dimensions
- ASIC dimensions
- Package view
- Specific process steps
- Cost breakdown

TABLE OF CONTENTS

VOLUME 1 : ANALYSIS REPORT

INTRODUCTION

THE INERTIAL MEMS MARKETS

- Market forecast in \$M, in units, in wafers
- Market drivers
- Technical solutions to answer the market drivers

THE DIFFERENT DETECTION PRINCIPLES FOR INERTIAL MEMS

- Manufacturing approaches
- Accelerometers
- Gyroscopes
- Magnetometers

PACKAGING TRENDS

- At the device level
- At the wafer-level

TEST OF INERTIAL MEMS

- Specificities for inertial MEMS testing
- Inertial MEMS - Off-line testing
- Inertial MEMS - Wafer test
- Inertial MEMS - Final test
- Cost of test and trends
- Test supply chain evolution
- Trends in inertial MEMS testing

COMPARATIVE ANALYSIS OF DIFFERENT INERTIAL GENERATIONS:

- Production cost breakdown:
 - MEMS
 - ASIC
 - Packaging & Test
- ASIC litho nodes
- Die size
- Package size
- Package type
- Comparative analysis in terms of:
 - Performances
 - Production cost for MEMS and ASIC
 - MEMS size
 - ASIC size
 - Package size
 - Year for market introduction

CONCLUSIONS

VOLUME 2 : REVERSE COSTING REPORT

For each of the devices below, the following information will be given: package characteristics, ASIC/MEMS dimensions, cross-section, MEMS process, cost breakdown.

LIST OF MEMS DEVICES COVERED INTO THE REPORT:

1. ST LIS331DLH
2. ST LIS3DH
3. Bosch Sensortec BMA180
4. Bosch Sensortec BMA250
5. Kionix KXTE9
6. Freescale MMA8450
7. Freescale MMA8451
8. Analog Device ADXL278
9. Analog Device ADXL346
10. Invensense IDG 1004
11. Invensense IDG 600/650
12. Invensense ITG3200
13. ST L3G4200D
14. VTI CRM3000
15. Sensordynamics SD740
16. SSS Pinpoint CRM100
17. Epson Toyocom XV-3500CB
18. Sony 2-Axis Gyro
19. Murata ENC-03RC-10-R A11
20. SensorDynamics SD746
21. VTI SCC1300
22. Invensense MPU6000
23. AKM AK8973S

WHO SHOULD BUY THE REPORTS

- **MEMS manufacturers**
 - Identify the key trends into inertial MEMS manufacturing
 - Monitor and benchmark your competitor's products
- **MEMS integrators**
 - Identify and evaluate different MEMS devices
- **Equipment manufacturers**
 - Identify the latest trends into manufacturing, packaging and testing

BIO



Dr. Eric Mounier has a PhD in microelectronics from the INPG in Grenoble. He previously worked at CEA LETI R&D lab in Grenoble, France in Marketing dept. Since 1998 he is a co-founder of Yole Developpement, a market research company based in France. At Yole Developpement, Dr. Eric Mounier is in charge of market analysis for MEMS, equipment & material. He is Chief Editor of Micronews, and MEMS'Trends magazines (Magazine on MEMS Technologies & Markets).

COMPANIES CITED IN THE REPORT

Acutronic, Advanced Microsensors, Advantest, Afore, Aichi, AIS/SSS, AKM, Analog Devices, ASE, Baolab, Bosch Sensortec, CascadeMicrotech, CEA Leti, Colibrys, Epson Toyocom, Freescale, Gladiator Technologies, Honeywell, Invensense, Jyve, Kionix, KYEC, Litef, Memsic, Multitest, Murata, Panasonic, Polytec, Qualtre, Rohm, Sensoror, Sensordynamics, Sony, SPEA, SSS, STM, Systron Donner, TEL, Teradyne, Thales, Tronics, VTI, VTT, Yamaha...

BIO



Laurent Robin is in charge of the MEMS & Sensors market research at Yole Developpement. He previously worked at image sensor company e2v Technologies (Grenoble, France) and at EM Microelectronics (Switzerland). He holds a Physics Engineering degree from the National Institute of Applied Sciences in Toulouse. He was also granted a Master Degree in Technology & Innovation Management from EM Lyon Business School, France.

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Beginning in 1998 with Yole Développement, we have grown to become a group of companies providing market research, technology analysis, strategy consulting, media in addition to finance services. With a solid focus on emerging applications using silicon and/or micro manufacturing Yole Développement group has expanded to include more than 40 associates worldwide covering MEMS, Microfluidics & Medical, Advanced Packaging, Compound Semiconductors, Power Electronics, LED, and Photovoltaic. The group supports companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to develop their business.

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TECHNOLOGY & MARKET REPORTS

- Collection of reports
 - Players & market databases
 - Manufacturing cost simulation tools
 - Component reverse engineering & costing analysis
- More information on www.yole.fr

MEDIA

- Critical news, bi-weekly: Micronews, the magazine
- In-depth analysis & Quarterly Technology Magazines: MEMS Trends- 3D Packaging PV Manufacturing - iLED - Power Dev'
- Online disruptive technologies website: www.i-micronews.com
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YOLE DÉVELOPPEMENT

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