MEMS Sensor Testing Challenges and Requirements

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Agenda

- Sensor Trends and Market Drivers
- Sensor Testing Challenges
- Sensor Testing Requirements
- Sensor Test Cell for High Volume Manufacturing
Sensors Trends

Improved performance, smaller size, lower cost

New sensor applications and packaging

Energy Harvesting?

Ultrasonic

WLCSP

3D Stacked SIP

Pressure

Humidity

Gas

Temperature

SNR

THD

SPL

Accuracy

Stability

Uniformity

9 DOF

10 DOF

12 DOF

Biosensors

Barometric Pressure

Environmental

Integration of multiple sensors

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19 September 2016
Sensor Trends WLCSP

- Wafer Level Package (Fan-In) unit count is growing at a CAGR of 9% between 2014 and 2019.

- Demand for WLCSP driven mainly by mobility customers due to low cost and smaller form factor (<50mm²)
  - Sensors, Connectivity, PMIC, Touch Controller, Camera, Transceiver/PA, ……

- Automotive and Internet of Things markets expected to grow MEMS WLCSP
The number of IoT connected devices is expected to grow to 30 – 50B devices by 2020.**

Wide variety of sensors needed to cover the long tail of applications in every market segment.

IoT will drive higher levels of integration of sensors, microcontrollers and RF in new innovative packaging (SiP, 3D,…).

Sources: **: (Cisco, Gartner) Images from Nest, Philips, Fitbit, iCon

** The IoT: The next step in internet evolution

“Killer” apps

Segment/industry/business specific

The long tail

Marc Jadoul Nokia March 2015

The “Thing” that senses our world

Sources: **: (Cisco, Gartner)
Images from Nest, Philips, Fitbit, Icon
Sensor Testing Challenges

- Stringent technical specifications
  - New sensors require higher performance and better accuracy
  - High performance sensors for competitive advantage and higher ASP

- High volume production and low Cost of Test
  - Billions of sensors shipped every year
  - High parallelism and UPH
  - Faster time to market

- Higher levels of integration
  - Multiple sensors integrated with demanding test challenges

- New technologies and applications
  - Innovative and smaller packaging (WLCSP, SiP, 3D, Embedded)
  - New sensor applications
  - Sensors for all markets (consumer, automotive, medical, industrial…)

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Sensor Testing for High Volume Manufacturing (HVM)

- Custom bench top engineering lab systems struggle to meet HVM requirements.
  - SITRI has the Xcerra solution which not only meets the engineering R&D requirements but is also capable of HVM production.

- HVM requires fully automated test cell that output millions of different sensor devices per month for low Cost of Test.

- Testing high accuracy specification sensor devices can be challenging in HVM.
  - High accuracy stimulus with high parallelism
  - Temperature accuracy and uniformity for large number of devices
  - Stable test conditions (low drift during test)
  - Isolation of test from environment (temperature/humidity, noise and vibration of test floor)
  - SNR requirements for Microphones
  - Achieving highest first pass yield
Environmental Sensors

- Growth of environmental sensors driven by smart devices
- Combination of pressure, temperature, humidity and gas in the same package
- Ideal Gas Law PV=nRT, model to predict the behavior of gas
  - Pressure related to temperature.
  - Humidity related to pressure and temperature.
- HVM test cell needs advanced temperature capability to meet stringent test requirements
  - Temperature Accuracy ±1°C
  - Temperature Uniformity ± 0.5°C
- Need stable test environment before start of test
  - Fast pressure switching time
Temperature Performance

Diagram displays delta T of +/-0.5°C at 125.6°C over nest array

**Performance**

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**Setup Tolerance**

PT100 Class A Tolerance

\[ dT = \pm (0.15 \text{ degC} + 0.002 \times T) \]

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MEMS Microphones

- Strong growth with the adoption of multiple microphones in consumer and mobility applications for noise cancellation, accurate voice recognition and HD video recording.
  - Future smart phones/ear buds will require up to 10 microphones

- Test solutions for previous generation microphones are not able to meet the technical and volume requirements for future high performance microphones
  - Need high parallel automated test solutions. Today solutions are able to test //144 sites.

- New technical requirements
  - Signal to Noise Ratio (SNR) 75dB
  - Sound Pressure Level (SPL) 140dB
  - Total Harmonic Distortion (THD) <0.5%
  - Digital output
  - Emerging ultrasonic applications
Optical Sensors

- Broad range of applications
  - Light detection for smart phone/home/automobile, bio-sensing (temperature, heart rate monitoring, blood oxygenation), gesture, proximity

- Test challenges:
  - Requires a wide range of light sources
    - RGB, ambient, multiple IR wave lengths, UV
  - Devices are small and fragile (chip on glass)
  - May need access to both sides of the device
  - May require testing at temperature
  - High volumes
High Parallelism and UPH

- To ship billions of sensors per year and get low Cost of Test, you need high UPH and parallelism
  - Minimize total test cells and CAPEX to meet volume demand
    - Minimize floor space, operators, maintenance, …

- Today 256 sites in a single touchdown. Target future +300 sites in parallel.

- Challenges in HVM
  - Handling large quantity of devices in parallel
  - Uniformity of stimulus
  - Uniformity of temperature across all devices throughout test for high yield
  - Contacting fine pitch devices (0.3mm)

InCarrier for //256 sites parallel test
Sensor Integration

- Need to test multiple DOF or stimulus
  - 9DOF inertial sensors
  - Environmental combo devices (pressure, temperature, humidity, gas)
  - 10/11/12 DOF: 9DOF + environmental, 9DOF + microphone
  - Fingerprint + optical

- Integration with other devices
  - Sensor, microcontroller, memory, RF and smart power

- Wide variety of packages and sizes
  - Multi-chip packages, caps, chip-on-glass, 3D…

- New requirements
  - Modularity to test all types of sensors
  - Flexibility to test all package types
  - Minimum number of insertions
  - Tester capable of testing integrated IoT devices
Testing MEMS WLCSP

- Growth in MEMS WLCSP

- Requires post saw test on singulated MEMS to ensure quality

- Challenges of handling MEMS WLCSP
  - Small size and thickness 1x1x0.2mm
  - Handler and MEMS stimulus needs to transport fragile singulated die
    - Minimizing handling steps challenging for pick and place handlers

- Other requirements
  - Input wafer ring/blue tape, output tape and reel
  - Stringent vision inspection requirements
  - Device tracking
  - RMA and retest challenges of WLCSP devices

Image by Gila Tool
Record Sensor Unit Shipments and Revenues

Wearables, vehicle automation and Internet of Things

- Unit shipment CAGR 12.4% 2015 – 2020
- Revenues CAGR 5.3% 2015 – 2020
- ASP CAGR -5.7% 2015-2020 (biggest decline in discrete inertial sensors)

Source: IC Insights
Sensor Test Cell for High Volume Manufacturing

- Fully automated test cell solution
  - Proven technical capability and experience in MEMS/sensor test
    - Advanced tri-temperature capability
    - Highest stimulus performance and accuracy
  - Highest parallelism and UPH
  - Integrated and optimized test cell for fast ramp and highest performance

- Flexible
  - High Return on Investment
    - Multi-use equipment for all types of devices (MCU, wireless, ….)
    - Standardized equipment instead of dedicated MEMS solutions
  - Modular MEMS stimulus for a wide range of sensor types
  - Ability to test integrated sensors with single insertion
  - Handle diverse package types and sizes on same equipment
    - WLCSP, strip, packages, less than 1x1mm size
  - Simple and fast change kit conversion

InStrip with InFlip MEMS Test Cell
InMEMS Modules Available for InStrip

- InFlip / InFlipM
  - Accelerometer Magnetometer

- InBaro / InHumid / InGas
  - Environmental Combo

- InGyro
  - 9DOF

- InPressure
  - TPMS

- InPhone
  - Microphone

InStrip Base Unit
Thank You