Teardowns and Cost analyses

MEMS Microphones Technical and Cost Review

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MEMS Market Briefing at Micromachine/MEMS 2012
S+C Core Activities

Reverse Costing
Teardown + Cost Analysis

Customer Specific
Catalog

Costing Tools
Training
The objectives of this presentation are:

✓ To get an overview on the state of the art in the design and manufacturing of various MEMS microphones.

✓ To understand which choices are validated by the industry, and which choices are still very diverse from one product to another.
MEMS Microphones Market Overview

- In 2011, Apple Inc. became the world’s largest purchaser of micro electro mechanical system (MEMS) microphones with a share of 27%.

- 3 analog MEMS microphones for iPhone 4/4S:
  - 2 in the handset + 1 in the headset

Microphone for noise-cancelling

Microphone for voice capture
MEMS Market Briefing

MEMS Microphones Market Overview

- In 2011, Knowles Electronics is representing 83% market share and is in the top 5 of the MEMS companies.
- Asian players are behind (AAC uses Infineon dies)

2011 market for MEMS microphones in mobile applications

SOURCE: Yole Développement.
MEMS Microphones Packaging

- Microphone packaging is very specific because:
  - A hole is needed
  - Shielding is generally used for immunity to radio frequency and electromagnetic interference
  - Acoustic chamber characteristic (cavity) is critical to get high performance
  - Configuration depends on the integration in the system: top port/ bottom port

MEMS Microphone Packaging (SOURCE: Yole Développement)
MEMS Microphones Packaging

- Package size is not necessarily related to the MEMS die but instead to industry standards
  - E.g. Akustica – AKU230
    - 0.70mm² Single-Chip Die in a … 3.76 x 4.72mm, and 1.25mm tall package!
  - Needs to be compatible with existing microphones used in laptops, cell phones… for easier adoption
  - When MEMS is further adopted, it is likely that we will see a significant decrease in the package size
MEMS Microphones Structure

- Capacitive sensor
  - Two capacitors electrodes
    - a membrane (diaphragm) and a backplate, separated by an air gap, forming a parallel plate capacitor
- Technology: surface & bulk micromachining

![Diagram of MEMS Microphone Structure](courtesy_of_knowles_electronics)
AAC Acoustic (from iPhone 4)

- Specificities of this component:
  - Released in 2010
  - Bottom-port, analog microphone
  - For cellphone
  - Only 3-pins
  - Large MEMS die: 1.8mm² (Infineon)
Akustica AKU230

- Specificities of this component:
  - Released in 2011
  - Top-port, digital microphone
  - For laptop
  - Single die: CMOS-MEMS integration
  - Cavity in the package
  - Ultra small microphone die: about 0.9mm² (But large package)
Analog Devices ADMP421

- Specificities of this component:
  - Released in 2009
  - Bottom-port, digital microphone
  - For smartphones & tablets
  - SOI substrate is used for the MEMS die
  - Small microphone die: about 1.1mm²
  - Large ASIC: close to 1.5mm² footprint
Epcos T4060

- Specificities of this component:
  - MEMS technology of Epcos (was infineon before)
  - Bottom-port, analog microphone
  - For consumer applications
  - Ultra small package footprint: 4.6mm²
  - HTCC substrate technology
  - No wirebonding: flip-chip is used
Knowles SPU0409

- Specificities of this component:
  - Released in 2010
  - Bottom-port, analog microphone
  - For cellphone applications
  - High number of pins (6) for an analog component
STMicroelectronics MP45DT01

- Specificities of this component:
  - Released in 2010
  - Top-port, digital microphone
  - For consumer applications
  - Large MEMS die: 1.8mm²
  - Wet etching is used for the cavity
  - Rather « large » ASIC: close to 1.5mm² footprint
### Package comparison

- **Epcos** packaging technology allows to get very compact components
  - Only 4.8mm² footprint. This is by far the smallest MEMS microphone package
  - Space is saved by using bumping instead of wirebonding
- **ST and Akustica** have very large packages
  - 2 times bigger than their competitors. But it is digital microphones that do not target the same applications (more focused on laptop than cellphone) → package size is driven by the end-application
  - Indeed although Akustica MEMS die is ultra small, the package needs to be quite big
DRIE is used by most players for etching the cavity. Only Omron (for ST microphone) is still using a wet etch technology (both front and back sides are etched)

- In general wet etching is known to be a cheaper process than DRIE
- But there is tradeoff: with wet etch the process may be cheaper but the component needs more silicon, which translates in higher cost

- HF vapor is used by every player for etching the sacrificial layer
MEMS die comparison

- Omron MEMS technology used by ST features a large MEMS cavity
ASIC comparison

ASIC size are very different from one product to another.

<table>
<thead>
<tr>
<th>ASIC Die Thickness (mm)</th>
<th>ASIC Die Footprint (mm²)</th>
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</thead>
<tbody>
<tr>
<td>500</td>
<td>0.5</td>
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<tr>
<td>400</td>
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<tr>
<td>300</td>
<td>1</td>
</tr>
<tr>
<td>200</td>
<td>1.25</td>
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<td></td>
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</tbody>
</table>

- **ADI ADMP421**
- **ST MP45DT01**
- **Akustica AKU230**
- **Epcos T4060**
- **AAC Acoustic**
- **Knowles SPU0409**

- **Akustica AKU230 (MEMS part included)**
- **Epcos T4060**
- **ST MP45DT01**
- **ADI ADMP421**
A very large variety of technology choice is observed for MEMS microphones

- The types of packages are different from one player to another. In particular Epcos is using a very specific package type and assembly process.
- The MEMS processes and design are more homogeneous: the type of structure is the same. However we observe slight differences of design (size of diaphragm, number of holes…).

The manufacturing costs are quite close from one player to one other

- From 12 to 16 cents