MEMS Microphones

iPhone X

MEMS report by Audrey LAHRACH
March 2018 – version 1
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Executive Summary

This full reverse costing study has been conducted to provide insight on technology data, manufacturing cost and selling price of the three different microphones found in iPhone X.

For microphone integration in the iPhone X, Apple has chosen the market’s top three microphone suppliers: Goertek, Knowles, and AAC Technologies.

The Apple iPhone X has four MEMS microphones: a front-facing top microphone, two front-facing bottom microphones, and a rear-facing top microphone. This layout is similar to previous iPhones, but the front-facing bottom-right microphone is now integrated in the speaker module. All four microphones share the same Apple-specific package dimensions, but with a different internal structure (number of substrate metal layers, embedded capacitance, ASIC, etc.).

In the iPhone X, we’ve observed changes to the microphones provided by Apple’s three suppliers:

- Goertek, which still relies on Infineon for die manufacturing, integrates Infineon’s technology with a double backplate, delivering a differential MEMS microphone. For the ASIC, Goertek has considerably reduced the die area by around 40% compared to the previous die.
- Knowles uses the same technologies as before, but one part has a new MEMS design and another part has an existing MEMS design.
- AAC uses the same MEMS microphone die as Goertek, but with a different ASIC.

Infineon is a big winner. By providing ASIC and MEMS dies to all of Goertek’s and AAC Technologies’ products, it now possesses a large share of the MEMS microphone market.

This report includes a complete comparison of the three suppliers’ microphones in terms of structure, process, and cost.
Executive Summary

The reverse costing analysis is conducted in 3 phases:

**Teardown analysis**
- Package is analyzed and measured
- The dies are extracted in order to get overall data: dimensions, main blocks, pad number and pin out, die marking
- Setup of the manufacturing process.

**Costing analysis**
- Setup of the manufacturing environment
- Cost simulation of the process steps

**Selling price analysis**
- Supply chain analysis
- Analysis of the selling price
Package Views & Dimensions

- **Package:** LGA 7-pin
- **Dimensions:** 3.33 x 1.96 x 0.82mm
- **Acoustic port:** 0.36mm
- **Marking:** L 170 737. GWM1

Package Top & Side View

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Package Opening

- Package opening reveals two dies connected together and to the PCB by wire bonding process.
- The ASIC die is covered with a glob-top and glued with an xxx.
- The MEMS die is glued with an xxx.

- Wire bonding number:
  - Nb between ASIC & Package: x
  - Nb between MEMS & ASIC: x

- Material: xxx
- Diameter: xx µm
- Length: xxµm
Overview / Introduction

Companies Profile

iPhone X Teardown

Goertek GWM1
  - Company Profile
  - Physical Analysis
    - Package
      - ASIC Die
      - MEMS Die
      - Comparison
    - Manufacturing Process Flow

Knowles KSM1

AAC ALM1

Cost Analysis

Selling Price Analysis

Feedbacks

About System Plus

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Package Cross-Section

Cross-Section Overview – Optical View

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ASIC Die View & Dimensions

Die Area: $xx\text{mm}^2$

(\(xxx \times xxxx\text{mm}\))

Nb of PGDW per 8-inch wafer: \(xxxx\)

(assuming \(xx\mu\text{m scribe line}\))

Pad number: \(x\)

- Connected: \(x\)

PGDW: Potential Good Dies per Wafer

Die Overview – Optical View

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The die marking includes:

- \(xxxx\)
ASIC Die Process

The process uses CMOS transistors.

MOS transistor gate length: $xxx \mu m$

Minimum size (technology node): $xx \mu m$
MEMS View & Dimensions

Die Area: xxxmm²
(xx x xxxm)

Nb of PGDW per 8-inch wafer: xxxx
(assuming 40µm scribe line)

Pad number: x
  • Connected: x

PGDW: Potential Good Dies per Wafer

The MEMS marking includes:
xxxx
  • Knowles Logo

Die Overview – Optical View
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MEMS Cross-Section – Bond Pad

MEMS Overview
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MEMS Cross-Section Overview
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MEMS Process Flow (3/4)
ASIC Front-End Cost

<table>
<thead>
<tr>
<th>Front-End</th>
<th>Goertek GWM1</th>
<th>Knowles KSM1</th>
<th>AAC ALM1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw wafer Cost</td>
<td>$xxx</td>
<td>$xxx</td>
<td>$xxx</td>
</tr>
<tr>
<td>Clean Room Cost</td>
<td>$xxx</td>
<td>$xxx</td>
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<tr>
<td>Equipment Cost</td>
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<tr>
<td>Consumable Cost</td>
<td>$xxx</td>
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<tr>
<td>Labor Cost</td>
<td>$xxx</td>
<td>$xxx</td>
<td>$xxx</td>
</tr>
<tr>
<td>Yield Losses Cost</td>
<td>$xxx</td>
<td>$xxx</td>
<td>$xxx</td>
</tr>
<tr>
<td>Wafer Front-End Cost</td>
<td>$xxx</td>
<td>$xxx</td>
<td>$xxx</td>
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<tr>
<td>Foundry Gross Profit</td>
<td>$xxx</td>
<td>$xxx</td>
<td>$xxx</td>
</tr>
</tbody>
</table>

- The unprobed wafer cost is estimated at $xxx for GWM1 ASIC, at $xxx for KSM1 ASIC and at $xxx for AAC ALM1.

- The main part of all wafer cost is due to the xxxxx with xxx%.

- We consider a foundry gross profit of xx% which result in a wafer price of $xxx for GWM1 ASIC, of $xxx for KSM1 ASIC and of $xxx for AAC ALM1.
## ASIC Die Cost

<table>
<thead>
<tr>
<th></th>
<th>Goertek GWM1</th>
<th>Knowles KSM1</th>
<th>AAC ALM1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
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<tr>
<td>Breakdown</td>
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</table>

The number of good dies per wafer is estimated at xxx for Goertek GWM1 ASIC, at xxx for Knowles KSM1 ASIC and at xxx for AAC Technologies ALM1 ASIC, which results in a respectively die cost of $xxx, $xxx and $xxx.

### Cost Analysis
- Summary
- Supply Chain
- Yields
- ASIC Die Cost
- MEMS Microphone Die Cost
- Packaging Cost
- Back-end Cost
- Component Cost

### Selling Price Analysis

### Feedbacks

### About System Plus
### MEMS Die Cost

**Cost Breakdown**

<table>
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<th></th>
<th>Goertek GWM1</th>
<th>Knowles KSM1</th>
<th>AAC ALM1</th>
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<tbody>
<tr>
<td><strong>Cost</strong></td>
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<tr>
<td><strong>Breakdown</strong></td>
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</tr>
</tbody>
</table>

- The number of good dies per wafer is estimated at $xxx for Goertek GWM1 ASIC, at $xxx for Knowles KSM1 ASIC and at $xxx for AAC Technologies ALM1 ASIC, which results in a respectively die cost of $xxx, $xxx and $xxx.
### Package Cost

The **packaging cost** is estimated at $xxx for Goertek GWM1, at $xxx for Knowles KSM1 and at $xxx for AAC Technologies ALM1.

The largest portion of the manufacturing cost is due to xxx cost at xx%.

<table>
<thead>
<tr>
<th>Package Manufacturing</th>
<th>Goertek GWM1</th>
<th></th>
<th>Knowles KSM1</th>
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<th>AAC ALM1</th>
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<tbody>
<tr>
<td>Substrate Cost</td>
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<td>Clean Room Cost</td>
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<td><strong>Total Cost</strong></td>
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</table>

The largest portion of the manufacturing cost is due to xxx cost at xx%.
Component Cost

<table>
<thead>
<tr>
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<th>Goertek GWM1</th>
<th>Knowles KSM1</th>
<th>AAC ALM1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASIC Die cost</td>
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<tr>
<td>MEMS Die cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packaging cost</td>
<td></td>
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<tr>
<td>Final test &amp; Calibration cost</td>
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<td></td>
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<tr>
<td>Yield losses cost</td>
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</tbody>
</table>

The component cost is estimated at $xxx for Goertek GWM1, at $xxx for Knowles KSM1 and at $xxx for AAC Technologies ALM1.
Estimated Selling Price

We estimate that suppliers realizes a gross margin of xx% on the component, which results in a final component price estimated at $xxx for Goertek GWM1, at $xxx for Knowles KSM1 and at $xxx for AAC Technologies ALM1.

This corresponds to the selling price for large volume to OEMs.
Related Reports

**REVERSE COSTING ANALYSES - SYSTEM PLUS CONSULTING**

**MEMS**
- Vesper VM1000 Piezoelectric Microphone
- STMicroelectronics MEMS Microphone iPhone 7
- Knowles MEMS Microphone iPhone 7
- Goertek MEMS Microphone iPhone 7

**MARKET AND TECHNOLOGY REPORTS - YOLE DÉVELOPPEMENT**

**MEMS**
- Acoustic MEMS and Audio Solutions May 2017

**PATENT ANALYSIS - KNOWMADE**

**MEMS**
- Knowles MEMS Microphones in Apple iPhone 7 Plus - Patent-to-Product Mapping
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Manufacturing Cost Comparison

AUTHORS:

Audrey Lahrach
Audrey is in charge of costing analyses for ICs, LCD and OLED displays and sensor devices. She holds a master’s degree in micro-electronics from the University of Nantes.

Nicolas Radufe (Lab)
Nicolas is in charge of physical analysis. He has a deep knowledge in chemical and physical analyses. He previously worked in micro-electronics R&D for CEA/LETI in Grenoble and for STMicro-electronics in Crolles.

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<td>First piezoelectric microphone could disrupt consumer applications.</td>
<td>The market for MEMS microphones and ECMs, micro-speakers and audio ICs will be worth $20B in 2022.</td>
<td>What are the main patented features of Knowles’ MEMS Microphones in the iPhone 7 Plus?</td>
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2. Mailing of the Products

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- and within a reasonable time for new Products or those delivered after the period of release.
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2.2 The Buyer is responsible for paying for the Products delivered.

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3.2 In the event of termination of the contract, or of misconduct, during the contract, the Seller will have the right to invoice the Seller for the Products sent, or to invoice the Seller for the Products already delivered at the order date.

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branch code: 00596
Account n°: 0175 008 1566 87
BIC or SWIFT code: CCFRFRPP
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