SiTime University Turbo Webinar Series

Silicon MEMS vs. Quartz Supply Chain

August 19-20, 2013
Agenda

• Benefits of a solid supply chain

• How are quartz timing products built?

• How are MEMS oscillators produced?

• A Comparison

• Summary
Benefits of a Solid Supply Chain

Best lead time for samples and production

• Samples available in 48-hours
  • Any frequency
  • Any package
  • Any supply voltage
  • Any frequency stability option

• 4-week production leadtime

Continuity of Supply
How Do We Do It?

- Standard silicon wafer production
- Standard plastic packaging

- Oscillators come out of assembly as blanks
  - Easiest way to hold wafer inventory prior to assembly and test
  - 4-weeks lead time from wafer-to-finished product

- Parts are programmed at production test
  - Easiest way to inventory packaged product
  - 1-2 week volume lead time
Quartz Resonator Construction

- Photolithography used to apply material to quartz and etch out resonator structure
- Cr-Au plating applied on top of quartz resonator
- Frequency adjustments by laser trimming
Construction of Quartz Oscillator

- CMOS die attach and wire bonding
- Quartz blank attached by conductive glue
  - Out gassing of glue - causes drift and aging
  - Dispensed amount influences mechanical parameters of resonator
  - Moving metal electrodes - cause drift
- Finished Package Assembly Process
  - Metal lid sealing by seal glass (out gassing) or welding (expensive)
  - Hermetic sealing is required to prevent oxidation and mass loading – drift
  - Laser marking
- Concentrated supply of raw material
  - 80% of quartz raw material is produced in Japan
  - Two ceramic package vendors control the market (Kyocera 80%, Sumitomo 20%)
SiTime MEMS Oscillator Construction-Production Flow

CMOS wafers
(TSMC 0.18um CMOS)

MEMS wafers
(Bosch, TowerJazz 0.25um, SOI)

QFN or WL-CSP Packaging
(ASE/Carsem/UTAC)

Final Test
(ASE/Carsem/UTAC)

Ship
Comparison of Manufacturing Fabs

Quartz: dicing and grinding

Quartz: manual assembly

MEMS: Modern 200mm Wafer Fab
## Supply Chain Comparison

<table>
<thead>
<tr>
<th>Processes</th>
<th>MEMS</th>
<th>Quartz Oscillators</th>
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<tbody>
<tr>
<td></td>
<td>- Standard CMOS tools and processes</td>
<td>- Proprietary processes</td>
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<td></td>
<td>- High volume batch processing</td>
<td>- Serial, single part processes</td>
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<tr>
<td>Fabs/Foundries</td>
<td>- Modern, standard</td>
<td>- Specialized, unique quartz fabs</td>
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<td></td>
<td>- Highly controlled</td>
<td></td>
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<tr>
<td></td>
<td>- Ultra clean</td>
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<tr>
<td>Scalability</td>
<td>- No capacity limit</td>
<td>- New lines required for any increase in capacity</td>
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<td>- Multiple sources to increase capacity</td>
<td>- Slow to ramp and react</td>
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<tr>
<td>Quality control</td>
<td>- CMOS standard</td>
<td>- Every part &amp; freq requires customer qualification</td>
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<td>- 6 sigma, SPC, JEDEC</td>
<td>- High customer audit effort</td>
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<tr>
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<td>- Single customer qualification for many freqs</td>
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<tr>
<td>Cost</td>
<td>- Low cost foundry</td>
<td>- Custom tooling</td>
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<tr>
<td></td>
<td>- Batch processes</td>
<td>- Strongly dependent on utilization</td>
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Quartz vs. MEMS: Manufacturing

**SiTime’s Silicon Oscillator Manufacturing**

- **Customer Order**
- **Die Bank**
- **Assemble, Test, Program, Ship**
- **Package, Test and Program, Ship**
- **3-5 weeks**

**Mechanical Quartz Manufacturing**

- **Customer Order**
- **Grow Quartz**
- **Build Quartz for Order**
  - Slice, Cut, Grind, Plate, Test, Calibrate
- **Assemble, Test, Age, Screen and Ship**
  - Package, Weld, Age, Test, Screen, Ship
- **8 – 16 weeks**

**Quartz vs. MEMS: Manufacturing**

- **Customer Order**
- **Grow Quartz**
- **Build Quartz for Order**
  - Slice, Cut, Grind, Plate, Test, Calibrate
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**SiTime**

- **SiTime’s Silicon Oscillator Manufacturing**
- **Customer Order**
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- **Package, Test and Program, Ship**
- **3-5 weeks**
SiTime – Sustainable Cost Advantage

Incremental reductions

Semi economy of scale

Cost

Quartz

SiTime

Today

2014

Limit
Summary

• MEMS has a simpler structure and manufacturing process

• Being programmable, MEMS have better lead time for samples and production

• Utilizing proven semiconductor processes, MEMS can ramp to volume from zero to millions quickly

• With standard processes available from multiple sources, MEMS is lower risk to supply

• MEMS structures and processes have proven themselves in accelerometers, gyroscopes and sensors shipping in billions every year
Contact Information

• For Questions, contact SiTime Technical Support
  Technicalsupport@sitime.com

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