SiTime University Turbo Seminar Series

July 29-30 2013
SiTime MEMS Advantages

The Smart Timing Choice™
Agenda

• Benefits of SiTime’s MEMS Fabrication Process

• Advantages of Silicon MEMS

• Design for High Q and low Stress Sensitivity

• Best Resistance to Shock and Vibration

• World Class Reliability
Silicon MEMS is Best for High Volume

**Silicon MEMS**
High volume, multi-sourced, scalable

- Capital-Lite
  - Standard fabs
  - TSMC, Bosch, Tower-Jazz
- Plastic packages, multi-sourced
  - Carsem, ASE, UTAC
- Smaller is cheaper, more robust

**Quartz**
Complex, single-sourced

- Capital intensive
  - Specialized lines by package
  - Scale only by adding factories
- Ceramic packages – one supplier controls 80% of supply
- Smaller is costly, more fragile

2.0 x 1.2mm SMD
1508 CSP

Quartz Resonator in 2.0 x 1.2mm SMD Pkg
Quartz Resonator in 1.6 x 1.0mm SMD Pkg
Advantages of Single Crystal Silicon Resonators

• Single Crystal Silicon resonators are compatible with standard CMOS processing
  • Enables fabless models and massive production scaling
  • Moore’s law advantage

• Single Crystal Silicon resonators can withstand very high encapsulation temperatures
  • Eliminates contaminants from resonator cavity

• Ultra-clean encapsulation means no frequency drift
  • Chemically and thermally scrubbed Silicon surface
  • Epitaxial reactor is designed to grow ultra-pure silicon crystals without defects
Advantages of Single Crystal Silicon Resonators

• EpiSeal Encapsulated single crystal silicon resonators do not drift
  • Other technologies require the use of metals, amorphous materials, polycrystalline materials, and epoxies.
  • Introducing other materials may cause fatigue or stress relaxation leading to frequency change and reliability issues.

• Single crystal silicon is an extremely repeatable and resilient material
  • Enables single-point room-temperature calibration
  • Outstanding mechanical toughness, stiffer than Quartz
Design of Resonators for Best Performance: Stress

- Anchor placement minimizes stress sensitivity
- Mechanical coupling between anchor and resonator reduces stress effects
- Resonator system design corrects for stress
Design of Resonators for Best Performance: Optimizing Q

• Resonator design adjusted to minimize Thermal Elastic Dissipation (TED)

• Resonator design adjusted to minimize Anchor Losses

• In-plane definition of features allows SiTime to tailor connection to anchors – difficult to achieve in quartz (epoxy attachment)
SiTime MEMS Oscillators are Inherently Robust Against Shock & Vibration

Proprietary Design

• Our Resonators are Designed Specifically for Low Sensitivity to Any External Mechanical Acceleration

• Single-Point, Center Anchored MEMS Resonator Virtually Eliminates Stress Error Sources

5 MHz Resonator

524 kHz Resonator

48 MHz Resonator
SiTime MEMS Oscillators are Inherently Robust Against Shock & Vibration

The resonator moving mass is extremely small → Large acceleration needed to cause sufficiently large force

SiTime MEMS Resonator Mass is 1000-to-3000 Times Smaller Than Quartz!

Silicon MEMS Resonator Mass
Independent of Package

Quartz Resonator Mass Varies with Pkg Size

5.0 x 3.2mm Package
SiTime MEMS Oscillators are Inherently Robust Against Shock & Vibration

The resonator structure operates like a very stiff spring→
Very difficult to affect through external force.

>1M $g$ needed before resonator touches any surfaces. 55,000 times greater than a Howitzer Cannon!
SiTime MEMS are Insensitive to Vibration

Vibration Sensitivity vs. Frequency

Up to 200x Better Performance

Vibration Sensitivity (ppb/g) vs. Vibration Frequency (Hz)

ppb/g error is calculated from the measured phase noise spurs at different vibration frequencies.
Best Quality and Reliability: Leveraging Outstanding Design, Materials, and Processes

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<tr>
<th>Metric</th>
<th>Actual</th>
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<tbody>
<tr>
<td>DPPM based on Customer Returns</td>
<td>0.14 DPPM</td>
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<tr>
<td></td>
<td>Based on 150 Million Units Shipped Below 100 DPPM is World Class</td>
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<tr>
<td>FIT</td>
<td>2 FIT</td>
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<tr>
<td></td>
<td>500 Million Hours</td>
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<td>15x Better than Quartz</td>
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Summary

• Best High Volume Manufacturing Because…
  • Leverages existing CMOS manufacturing equipment and processes
  • No investment in customized manufacturing line

• Best in Performance Because…
  • Single Crystal Silicon is a superior performing material
  • Resonators are designed for low stress sensitivity and high Q

• Best Shock & Vibration Because…
  • Smaller and Stiffer MEMS resonator vs Quartz
  • Center Anchored MEMS Design
  • For more performance details, see the December 2012 webinar

• Best Reliability—Because we are 100% Silicon
  • 500MHr MTBF (2 FIT)
Contact Information

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

• For Turbo Webinar pdf Downloads on SiTime’s Web Site
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