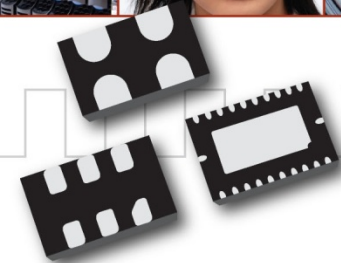




SiTime University Turbo Seminar Series

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

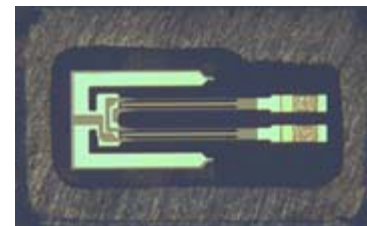
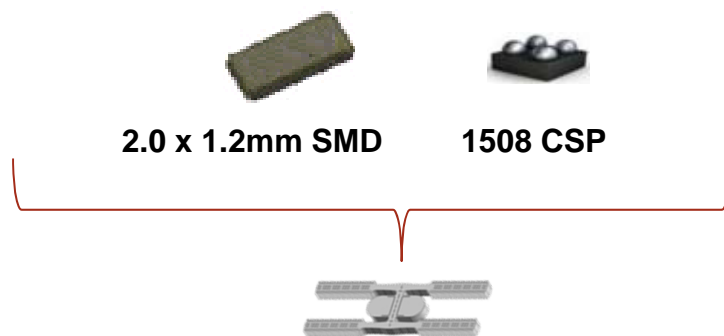
Quartz

High volume, multi-sourced, scalable

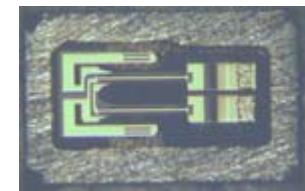
Complex, single-sourced

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

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



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)

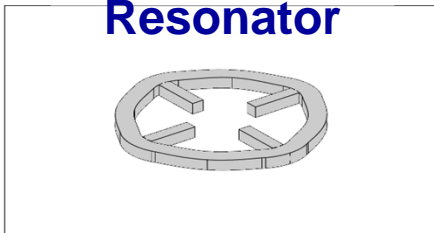
SiTime MEMS Oscillators are Inherently Robust Against Shock & Vibration



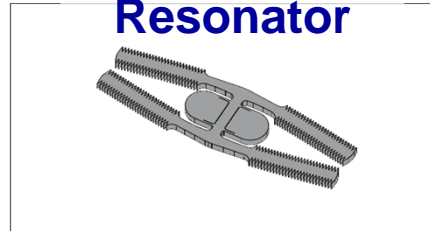
Proprietary Design

- 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**



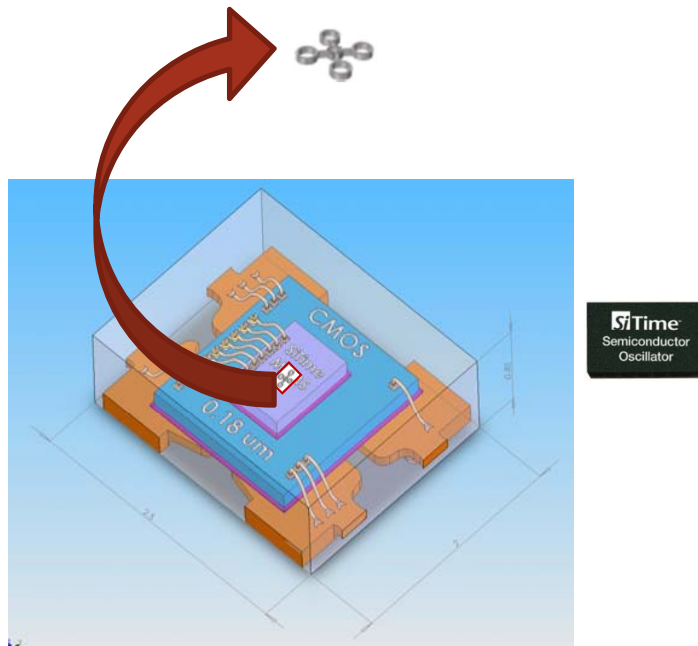
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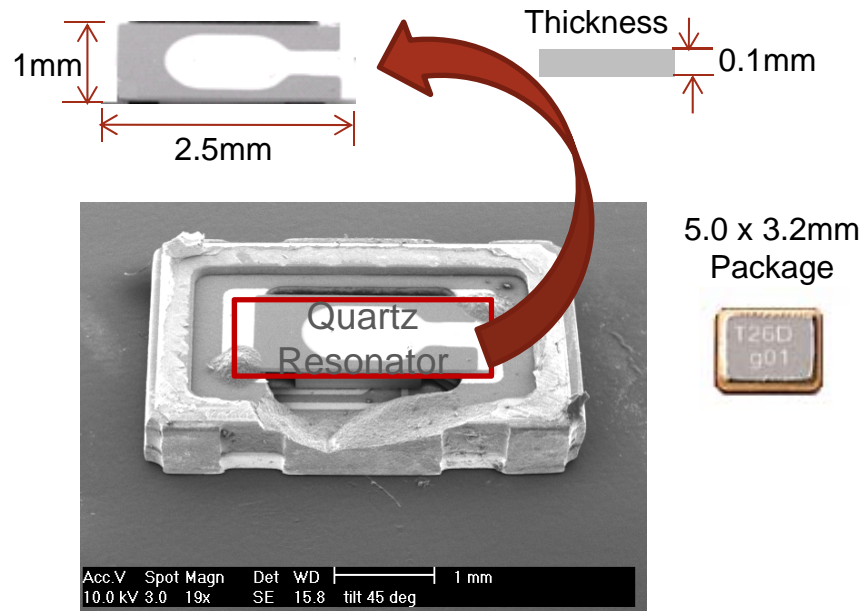
The resonator moving mass is extremely small → Large acceleration needed to cause sufficiently large force

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



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.

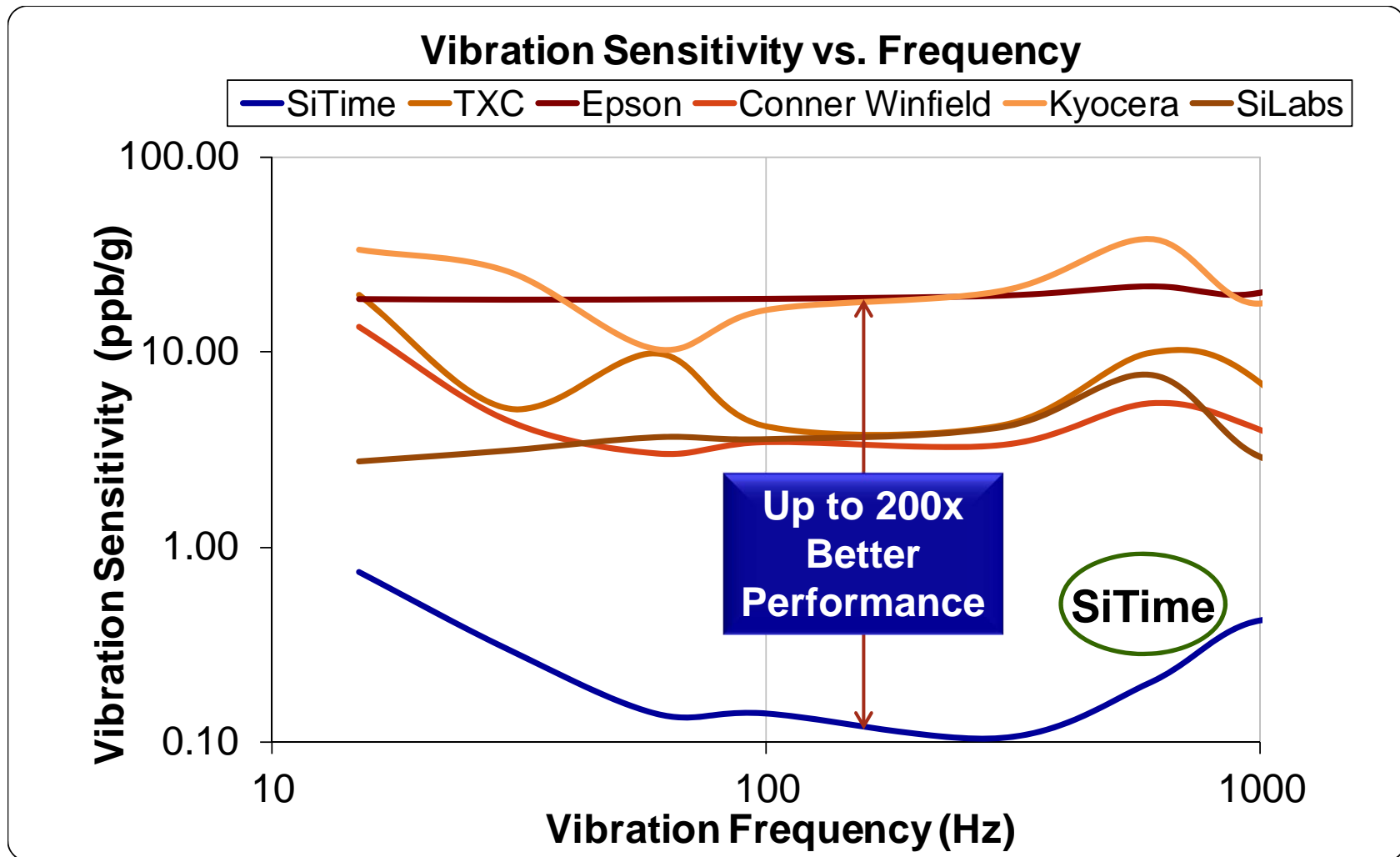
>1M g needed before resonator touches any surfaces. 55,000 times greater than a Howitzer Cannon!



Howitzer Cannon Launches a Ballistic with a Force of 18k g

0010101010 [AT] © www.vitalphoto.com

SiTime MEMS are Insensitive to Vibration



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



Metric	Actual
DPPM based on Customer Returns	0.14 DPPM Based on 150 Million Units Shipped Below 100 DPPM is World Class
FIT	2 FIT 500 Million Hours 15x Better than Quartz

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**
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- **For *Turbo Webinar* pdf Downloads on SiTime's Web Site**
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