Agenda

• SiTime’s Silicon MEMS Oscillator Construction
  • Built for High-Volume Mass Production

• Best Electro-Magnetic Susceptibility (EMS) Performance

• Best Power-Supply Noise Rejection

• Best Resistance to Shock and Vibration

• World Class Reliability
MEMS Resonators For All Clocking

**5 MHz Resonator**
- 5MHz resonator
- In production since 2007

**48 MHz Resonator**
- <1ps phase jitter
- In production since 2011

**524 kHz Resonator**
- For timekeeping, RTC
- In production since 2010
SiTime’s MEMS Oscillator has the Most Flexible System Architecture
Resilience Performance
Best
Electro-Magnetic Susceptibility (EMS) Performance
EMS vs EMI

We are analyzing the oscillator’s susceptibility to electro-magnetic radiated fields (EMS)

EM-Field
Produced by Component

Radiated EM-Field from External Sources (Other ICs, modules, etc.)

EMI
Electro-Magnetic Interference

EMS
Electro-Magnetic Susceptibility
EMS Test Setup

PNA – Agilent E5052B Phase Noise Analyzer
DSA – Agilent DS90604A Digital Signal Analyzer
Best EMS Performance -- LVCMOS

SiTime vs Quartz Single-Ended XO Electro-Magnetic Susceptibility (EMS)

Average Spurs (dB)

-90
-85
-80
-75
-70
-65
-60

NDK
Kyocera
TXC
SiTime

SiTime up to 4x Better
Best EMS Performance – LVDS/LVPECL

LVDS/LVPECL Electro Magnetic Susceptibility (EMS)

-90  -80  -70  -60  -50  -40  -30

Kyocera  Epson  TXC  Discera  CW  SiLabs

SiTime up to 54x Better
How SiTime Delivers the Best EMS Performance

- **Design & MEMS Structure**
  - Differential architecture for best common mode rejection
  - No sensitive, high-impedance nodes
  - MEMS ultra-small resonator size minimizes antenna pick-up effects compared to larger quartz resonator

- **SiTime’s MEMS Resonators are Electrostatically Driven—Inherently Immune to EMI**
  - Quartz Devices are Piezoelectric and are More Susceptible to EMI

- **Definition of EMS**
  - EMS is a measure of the timing device’s immunity to radiated EMI sources from other electronic components
Best Power-Supply Noise Rejection
Best Power-Supply Noise Rejection--LVCMOS

Power Supply Noise Rejection

- SiTime
- NDK
- Epson
- Kyocera

Integrated Phase Jitter per mVp-p injected noise (ps/mv)

Power Supply Noise Frequency (kHz)

SiTime Up To 7x Better
How SiTime Delivers the Best Power-Supply Noise Rejection

• Best Oscillator Circuit Design
  • Differential Design for Best Common Mode Rejection
  • 2 Layers of Linear Regulation for Best Supply Noise Immunity
  • Internal Bypass Decoupling for High-Freq. Noise Filtering

• 100% In-House Mixed-Signal Design
  (not available from quartz)
  • Continuous improvement and optimization

• Definition of Power Supply Noise Rejection and test condition
  • Noise on the power supply increases jitter on the clock output. The ability of a timing device to reject this power supply noise is Power Supply Noise Immunity
  • 50mVpp noise injected onto power supply, changing freq. DUT Vdd supply bypassed with 0.1µF//10µF
Best Shock and Vibration Performance
Mechanical Shock Test Setup

Reference pin 1 mark for orientation

Vertical drop on guide rail

Controller → Shock Tester

Continuous Time Interval Analyzer

Power Supply

Z

Y

X

X, Y

Z
Best Performance Under Shock — LVCMOS (500 g)

Best Performance Under Shock — LVDS/LVPECL (500 g)

MIL-STD-883F Method 2002, condition A: half sine wave shock pulse, 500 g, 1ms
Random Vibration Test Setup

Controller → Power Amp → Shaker

Reference pin 1 mark for orientation

1-D linear displacement
Sine or random composite waveform

Phase Noise Analyzer

Power Supply

X, Y, Z reference pins mark for orientation or random sine
Best Phase Jitter Performance Under Vibration – LVDS/LVPECL

Random vibration profile: MIL-STD-883F Method 2026, Condition B at 7.5g rms. Data plot shows the induced jitter under vibration. Initial phase jitter (no vibe) is subtracted.
Best Phase Jitter Performance Under Random Vibration

**SiTime:** $5.72 \text{ps}_{\text{RMS}} \text{ IPJ}^1$

**Epson:** $89 \text{ps}_{\text{RMS}} \text{ IPJ}^1$

**TXC:** $61 \text{ps}_{\text{RMS}} \text{ IPJ}^1$

**Kyocera:** $100 \text{ps}_{\text{RMS}} \text{ IPJ}^1$

Induced Phase Jitter: $\sqrt{(\text{Jitter}_{\text{vibe}})^2 - (\text{Jitter}_{\text{no vibe}})^2}$
Best Stability Performance Under Vibration—LVCMOS & LVDS/LVPECL

Vibration Sensitivity vs. Frequency

<table>
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<tr>
<th>Vibration Sensitivity vs. Frequency</th>
<th>SiTime</th>
<th>TXC</th>
<th>Epson</th>
<th>Conner Winfield</th>
<th>Kyocera</th>
<th>SiLabs</th>
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ppb/g error is calculated from the measured phase noise spurs at different vibration frequencies.
SiTime Delivers 0.1 ppb/g Performance in a Plastic Package

- Putting 0.1 ppb/g sensitivity in perspective
- Quartz requires very specialized packaging to achieve low G-sensitivity performance.
- All SiTime parts are highly resistant to shock and vibration in a standard plastic package—no special packaging requirements!

Quartz Low G-Sensitivity Solution

Quartz 0.4 ppb/g device
9 x 14 x 6.2 mm

SiTime Standard MEMS XO

SiTime 0.1 ppb/g Device
2.0 x 1.6 x 0.75 mm
What Makes SiTime’s Silicon MEMS Reliability and Resilience Superior?
SiTime’s Silicon MEMS XO vs. Quartz XO

Functionally Similar…
- Both Require a Resonator…
- Both Require an Oscillator Die…

…But Different!

Oscillator Die

MEMS Resonator

Plastic Package

Oscillator Die

Quartz Resonator

Ceramic Package
SiTime MEMS Oscillators are Inherently Robust Against Shock & Vibration

1. 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!

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**Silicon MEMS Resonator Mass**

Independent of Package

**Quartz Resonator Mass Varies with Pkg Size**

![Silicon MEMS Resonator Image](image1)

![Quartz Resonator Image](image2)
SiTime MEMS Oscillators are Inherently Robust Against Shock & Vibration

2. 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 $g$
SiTime MEMS Oscillators are Inherently Robust Against Shock & Vibration

3. 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
Putting it All Together With World Class Reliability
Up to 35X Better Reliability Than Quartz

- **SiTime**: 500 million hours
- **IDT (Fox)**: 38 million hours
- **Epson**: 28 million hours
- **TXC**: 16 million hours
- **Pericom**: 14 million hours

Mean Time Between Failure (Million Hours)
Summary

• Best EMS Performance Because…
  • Best Mixed-Signal Design Methodology and MEMS structure
  • Electrostatically driven MEMS is more resistant to EMS

• Best Power-Supply Noise Rejection Because…
  • In-House Analog Design Expertise
  • Differential Oscillator Design

• Best Shock & Vibration Because…
  • Smaller and Stiffer MEMS resonator vs Quartz
  • Single-point, Center Anchored MEMS Design

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