Elite Platform™ – Transforming the Telecom and Networking Timing Market

September 2016

Confidential Until Sept 26, 2016
Rich Timing Content in All Electronics

Only SiTime can Provide Higher Performance, Smaller Size, Lower Power

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SiTime - The Timing Leader

$6B Timing Market
Market CAGR – 5%
MEMS CAGR – 65%

Technology Leader
100 Patents – MEMS, Analog, Systems
3-5 years ahead

Market Leader
500 MU shipped, 1BU by 2018
1000 Design Wins in 5 market segments
90% share of MEMS timing

Product Leader
Programmable – 200k part numbers
Fabless advantage
$6 Billion Timing Market - Fragmented

**Frequency Control**
- X, XTAL
- XO, VCXO, TCXO, OCXO
- 1 output
- $3.5 B

**Si Timing**
- CG, Buffer
- Multi-output
- $1B

**Systems**
- $1B

**Epson, Kyocera, 100 others**
- Quartz crystals
- Resonators, oscillators
- No analog expertise
- Large capex
- 20% GM

**IDTI, SLAB, MSCC, TI, ADI, 15 others**
- Analog & PLLs
- Clock Generators, Buffers
- No freq. control expertise
- Low capex
- 60% GM

**MSCC, 5 others**
- Modules, software
- Custom built
- 80% GM

Source: CS&A, SiTime
SiTime Unifies the $6B Timing Market

- Frequency Control: $3.5B
- Silicon Timing: $1B
- Systems: $1B

SiTime

- Proven MEMS
- High performance analog
- Systems – core competency
- Low capex
- Large barriers to entry

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Typical Applications that use SiTime’s MEMS Oscillators

NSST: Networking, Server, Storage, Telecom

Industrial & Automotive

Consumer

Mobile, Wearables & IoT

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SiTime – Best Quality Timing Solutions

SiTime – 500 Million Units Shipped
Zero MEMS Field Failures
Lifetime Warranty

![Graph showing DPPM comparison between Tier 1 Quartz, Tier 2 Quartz, and SiTime](image)

- **Tier 1 Quartz**: SiTime - (1.5 DPPM)
- **Tier 2 Quartz**: 150 DPPM

Lower DPPM is Better

Source: SiTime & customers

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Semiconductor Expertise Drives 250x Stability Improvement in 10 Years

- **Industrial Control**: 25 ppm
- **Cloud Server**: 10 ppm
- **Telecom PBX**: 5 ppm
- **Small Cell**: Elite Super-TCXO, 0.1 ppm

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Semiconductor Expertise Drives 800x
Jitter Improvements in 10 Years

Typical Values

- 2006
  - Microprocessor: 175 ps
  - Graphics Card: 30 ps
  - Computing Server: 15 ps

- 2010
  - Cloud Server: 1 ps

- 2016
  - 100 GB Ethernet: 0.23 ps
  - Elite DE XO: 0.23 ps

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Allan Deviation for Wireless Infrastructure – 30,000x Improvement in 10 Years

SiT8002
ADEV 1e-6

SiT8208
ADEV 3e-9

Elite Super-TCXO
ADEV 3e-11

GPS Requirement

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Silicon Always Wins

Highest Performance, Best Reliability, Smallest, Lowest Power

Quartz

MEMS
Elite Platform™
Super-TCXOs and Oscillators

MEMS Solutions to Long-Standing Timing Problems in Telecom and Networking
Network Densification Requires Innovation in Timing Technology

- **NSST**[1] – much higher performance, denser deployment, harsher environment
- Quartz crystal technology suffers in real world conditions[2]
- **Dynamic timing performance** is crucial in NSST
  - Maintain performance in airflow, rapid temperature change
  - Vibration immunity for pole-mount / curbside deployment
  - Support 105°C for outdoor environments
  - Minimize impact of EMI and other noise sources

1. NSST – Networking, Server, Storage, Telecom
Elite Platform Uniquely Delivers Best Timing Under Real World Conditions

**Best Stability**
- Temperature range
- Temperature ramp
- No activity dips
- Freq. slope over temperature
- VDD / Load

**Best Short Term Stability**
- ADEV
- Wander (MTIE / TDEV)
- Static and in airflow

**Best Robustness**
- Vibration
- Shock
- PSNR

**Rich Feature Set**
- Frequency range
- Differential output
- Digital frequency control
DualMEMS™ with TurboCompensation™ Enables Highest Dynamic Performance

**TempFlat™ MEMS Resonator**
- No aging
- No activity dips
- 30x better vibration immunity

**DualMEMS™ Temp Sensing**
100% Thermal Coupling
- 30 µK, 10x more accurate
- 350 Hz tracking, 40x faster
- Airflow, temp ramp resistant

**Low Noise CMOS Enabling Frequency Agility**
- 1 to 700 MHz, steps in mHz
- 0.02 ps/mv PSNR, 5x better
- In-system programmability

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Elite Platform Based MEMS Timing Solutions for Infrastructure

- **Precision MEMS Super-TCXO**
  - 1 to 220 MHz, ±0.1 ppm, Stratum 3, +105°C
  - Resilient to rapid temp change or airflow

- **MEMS Super-TCXO**
  - 1 to 220 MHz, ±0.5-2.5 ppm, +105°C
  - No activity dips

- **Ultra-low jitter differential MEMS Oscillator**
  - 10 to 700 MHz, ±10 ppm, 0.23 ps jitter, +95°C
  - 0.02 ps/mv PSNR, 3.2 x 2.5 mm package

- **High Temp, high reliability MEMS VCXO**
  - 1 to 700 MHz, +105°C, ±25 to ±3600 ppm pull range
  - 0.1 ppb/g vibration resistance
Elite Addresses High Precision Timing Demand in Infrastructure Markets

SyncE, Optical
Small Cell
Basestation
CMTS and Video

Smart Grid
Cloud Servers
Industrial GPS
Instrumentation
Elite’s Superior Air Flow Immunity Ensures Data Link Robustness

Core Router Cooling

- **Problem**: Quartz air flow sensitivity causes data link and packet loss
- **Solution**: Elite MEMS air flow immunity ensures robust data link and throughput
- **Specification**: ADEV, up to 38x better
Elite’s Best Vibration Immunity Improves Mobile Quality of Service

- **Problem**: Quartz vibration sensitivity causes call drops and loss of data link
- **Solution**: MEMS vibration immunity enhances QoS (no call drop or link loss)

Small Cell

![Small Cell Image](image)

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**Diagram:**
- **Phase Noise (dBc/Hz)**
- **Frequency Offset (Hz)**
- **Quartz TCXO** vs. **Elite Super-TCXO**
- **Vibration - Call drops**
- **20x better, no call drops**

*MIL-STD-883F Method 2026, freq. range 15 Hz to 2 kHz, total vibration intensity 7.5 g rms*
Elite’s Dynamic Stability Enables Smaller, Lower Power IEEE1588 Systems

Small Form Factor IEEE1588 Grandmaster

- **Problem:** 1 ppb/°C spec for IEEE1588, OCXO required
  - Power hungry
  - Large size

- **Solution:** Elite Super-TCXO, 1 ppb/°C
  - 70% lower power
  - 50% smaller

±20 ppb Quartz OCXO

<table>
<thead>
<tr>
<th>±100 ppb Elite Super-TCXO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ppb/°C ΔF/ΔT</td>
</tr>
</tbody>
</table>

9 mm x 7 mm

6 mm x 4.9 mm
Elite’s Exceptional PSNR Eliminates LDO

Problem: Quartz accuracy prone to power supply noise, requiring dedicated LDO

Solution: Elite – no LDO required
- 0.2 - 0.02 ps/mv PSNR
- Accurate clock with low cost switching power supply
Elite’s In-system Programmability Improves System BOM, Noise Immunity

- **Problems**: Legacy designs require a DAC
  - Prone to noise
  - Extra component

- **Solution**: Elite MEMS
  - Eliminate DAC with I2C
  - Immune to board noise with digital control
## Additional Performance Advantages

<table>
<thead>
<tr>
<th>Specification</th>
<th>Elite Super-TCXO</th>
<th>Quartz TCXO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Stability vs. VDD</td>
<td>&lt; 10 ppb for ±10%</td>
<td>10 ppb for ±1%</td>
</tr>
<tr>
<td>Frequency Stability vs. Load</td>
<td>&lt; 5 ppb for ±2 pF</td>
<td>10 ppb for 1.5 pF</td>
</tr>
<tr>
<td>$\Delta F/\Delta T$ (Frequency vs. Temp. Slope)</td>
<td>1-5 ppb/°C</td>
<td>10 ppb/°C</td>
</tr>
<tr>
<td>PSNR</td>
<td>SE: 0.2 ps/mV DE: 0.02 ps/mV</td>
<td>SE: 0.4 ps/mV DE: Not known</td>
</tr>
<tr>
<td>f-vs-Vctrl Linearity (VC-TCXO)</td>
<td>0.1%</td>
<td>5%</td>
</tr>
<tr>
<td>Vctrl Tuning Effect (f-vs-Temp Degradation Across Vctrl Values)</td>
<td>10 ppb</td>
<td>200 to 2000 ppb (VCTCXO)</td>
</tr>
</tbody>
</table>
## Elite Offers the Best Features

<table>
<thead>
<tr>
<th>Specification</th>
<th>Elite</th>
<th>Quartz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency Range</strong></td>
<td>SE: 1 - 220 MHz&lt;br&gt;DE: 10 - 700 MHz&lt;br&gt;Programmable</td>
<td>SE: 10 - 52 MHz&lt;br&gt;DE: 10 - 200 MHz&lt;br&gt;Fixed frequencies</td>
</tr>
<tr>
<td><strong>Differential Outputs</strong></td>
<td>LVPECL / LVDS / HCSL</td>
<td>LVPECL</td>
</tr>
<tr>
<td><strong>Single-Ended Outputs</strong></td>
<td>LVCMOS and Clipped-Sine&lt;br&gt;Programmable</td>
<td>LVCMOS and Clipped-Sine&lt;br&gt;Fixed</td>
</tr>
<tr>
<td><strong>Temperature Readout</strong></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>High Resolution Digital Frequency control</strong></td>
<td>I2C</td>
<td>I2C</td>
</tr>
<tr>
<td><strong>Programmable Rise / Fall Time (LVCMOS) for Lower EMI</strong></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Frequency Select</strong></td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Elite’s Industry Firsts - Solve Deep-Rooted Timing Challenges in Telecom / Networking

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>30x Higher Dynamic Performance</td>
<td>Best performance under airflow, rapid temperature change</td>
</tr>
<tr>
<td>No Activity Dips</td>
<td></td>
</tr>
<tr>
<td>10x Better Dynamic Stability,</td>
<td>Replace OCXO in IEEE1588</td>
</tr>
<tr>
<td>1ppb/°C ΔF/ΔT</td>
<td>66% lower power, 50% smaller</td>
</tr>
<tr>
<td>30x greater vibration resistance</td>
<td>Ensure continuous operation in high vibration environment</td>
</tr>
<tr>
<td>0.1 ppb/g</td>
<td></td>
</tr>
<tr>
<td>-40 to 105 °C Operation</td>
<td>Uniquely enables fanless outdoor equipment</td>
</tr>
<tr>
<td>±100 ppb stability</td>
<td></td>
</tr>
<tr>
<td>Stratum 3 with In-system Programmability</td>
<td>Improve system BOM, multi-protocol support and noise immunity</td>
</tr>
</tbody>
</table>
Types of Timing Devices

Additional Information
Resonator, Oscillator and Clock Generator

Resonator or Crystal (X, XTAL)
- Passive device
- Need ext. oscillating circuit
- 2 terminals used

Oscillator (XO, TCXO, VCXO, ....)
- Active device
- 2 chips in pkg.
- 4, 6, 10 terminals

Clock Generator (CG)
- Active IC
- Need ext. clock reference
- Many terminals / outputs
## Frequency Control – Types of Products

<table>
<thead>
<tr>
<th>Product Type</th>
<th>kHz or MHz</th>
<th>Stability (PPM)</th>
<th>Market Price</th>
<th>SiTime</th>
</tr>
</thead>
<tbody>
<tr>
<td>XTAL (Resonator)</td>
<td>Both</td>
<td>20 – 100</td>
<td>$</td>
<td>√~</td>
</tr>
<tr>
<td>XO / SPXO (Oscillator)</td>
<td>Both</td>
<td>10 – 100</td>
<td>$ - $$</td>
<td>✓</td>
</tr>
<tr>
<td>VCXO (Voltage Controlled Oscillator)</td>
<td>MHz</td>
<td>10 – 100</td>
<td>$ - $$$</td>
<td>✓</td>
</tr>
<tr>
<td>Mobile TCXO (Temperature Compensated Oscillator)</td>
<td>MHz</td>
<td>0.5 – 2.5</td>
<td>$ - $$</td>
<td>√~</td>
</tr>
<tr>
<td>Infrastructure TCXO (Temperature Compensated Oscillator)</td>
<td>MHz</td>
<td>0.28 – 10</td>
<td>$$$$</td>
<td>✓</td>
</tr>
<tr>
<td>Super-TCXO (TCXO with best dynamic stability)</td>
<td>Both</td>
<td>0.1 – 5</td>
<td>$ - $$$ - $$$$$</td>
<td>✓</td>
</tr>
<tr>
<td>OCXO (Oven Controlled Oscillator)</td>
<td>MHz</td>
<td>0.001 to 0.05</td>
<td>$$$$</td>
<td>√~</td>
</tr>
</tbody>
</table>

- Stability / Accuracy – Lower PPM is Better
- √~ – Future Product
## Oscillator Type – End Applications

<table>
<thead>
<tr>
<th>Oscillator Type</th>
<th>Special Function</th>
<th>End Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>XO or SPXO</td>
<td>N/A</td>
<td>Everywhere a clock is needed (consumer, industrial, etc.)</td>
</tr>
<tr>
<td>VCXO</td>
<td>Output fine-tuned by up to 3600ppm</td>
<td>Clock synchronization in Telecom, Broadband, Video &amp; Instrumentation</td>
</tr>
<tr>
<td>Mobile TCXO</td>
<td>N/A</td>
<td>Mobile phone, tablet, data cards, wearables</td>
</tr>
<tr>
<td>Super VCTCXO / TCXO</td>
<td>Dynamic performance</td>
<td>High performance equipment (Networking, small cell, industrial GPS, Satellite, SyncE, Microwave backhaul)</td>
</tr>
<tr>
<td>OCXO</td>
<td>Oven-controlled, ultra low noise</td>
<td>High performance equipment (Networking, small cell, industrial GPS, Satellite, IEEE1588, SONET)</td>
</tr>
<tr>
<td>SSXO</td>
<td>Spread %</td>
<td>Reduce EMI in system – industrial, Office automation, Consumer</td>
</tr>
<tr>
<td>DCXO</td>
<td>Digital control</td>
<td>Replaces VCXO, control via I2C / SPI</td>
</tr>
<tr>
<td>FSXO</td>
<td>Pin-selectable Frequency</td>
<td>Low volume, high mix, BOM reduction</td>
</tr>
<tr>
<td>ISPXO</td>
<td>I2C/SPI programmable</td>
<td>Prototyping, Low volume, high mix</td>
</tr>
</tbody>
</table>