

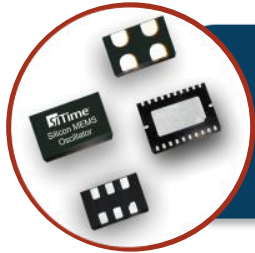


# Emerald Platform™ OCXO – Transforming Precision Timing for 5G

October 2018

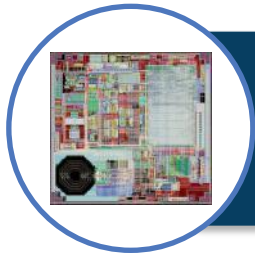
Confidential Until Nov 5, 2018

# SiTime - Only Company Focused on Timing



## Leader in Timing

- 90% share of MEMS timing market
- Billion units shipped



## \$6B Market

- 180 BU opportunity by 2025
- Focus on Comms-5G, Mobile-IoT, Automotive



## Technology Leader

- Leader in MEMS, Analog, Systems, 100 patents
- 5 years ahead of competition



## Top 3 in Semi Growth

- 10,000 customers, 200 applications

# SiTime's Engineering Core Competencies



MEMS

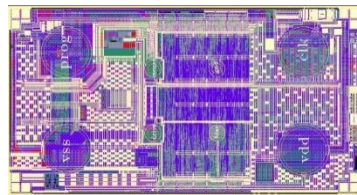
PLL

Temp Comp

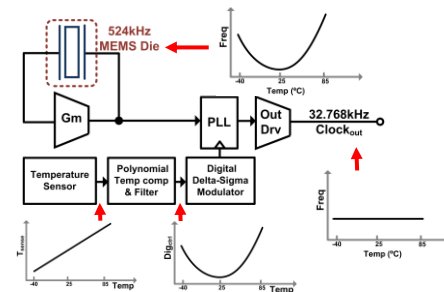
Package



Resonator

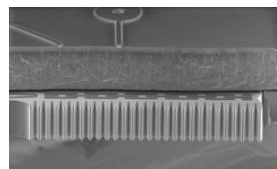


Mixed-Signal CMOS Design



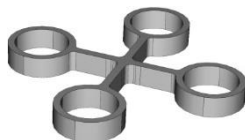
Highest Performance

# Disrupting Timing with Innovation Firsts



2007

100% Silicon



2011

Optimized Die Size



2013

80% Smaller  
4x More Accurate



2015

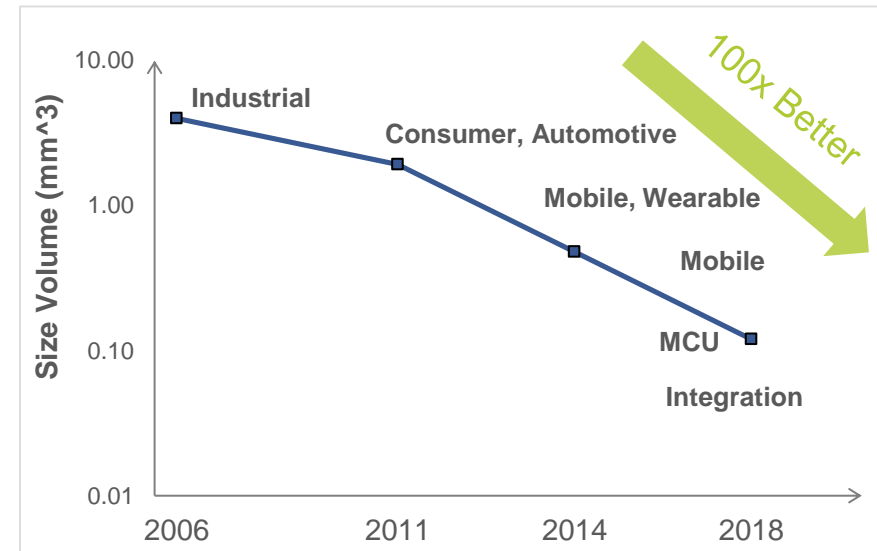
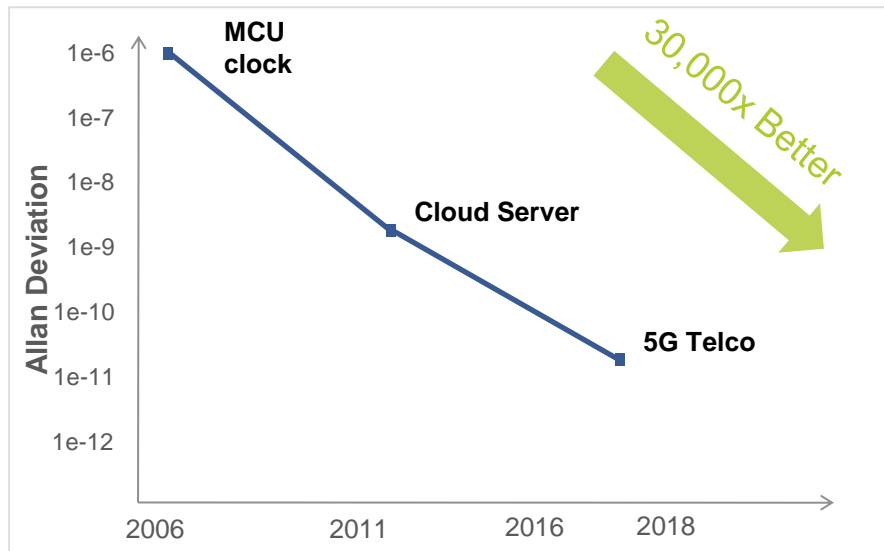
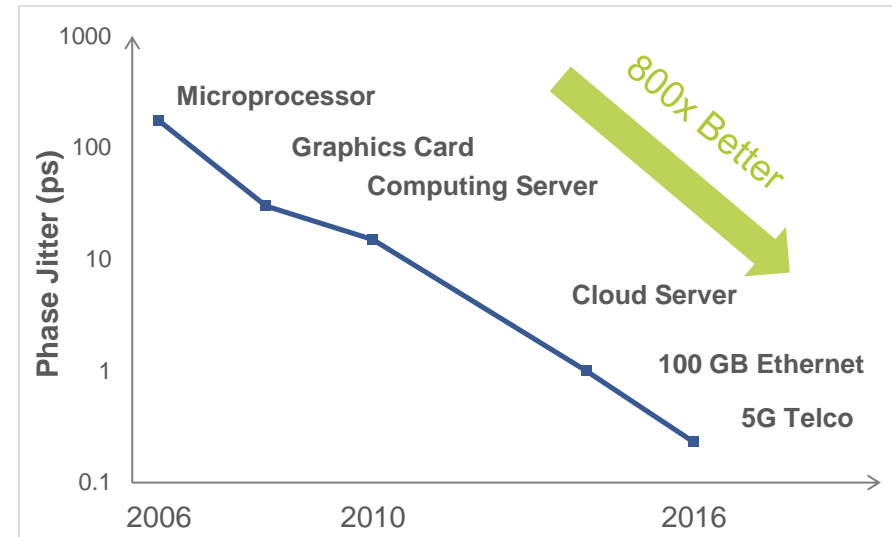
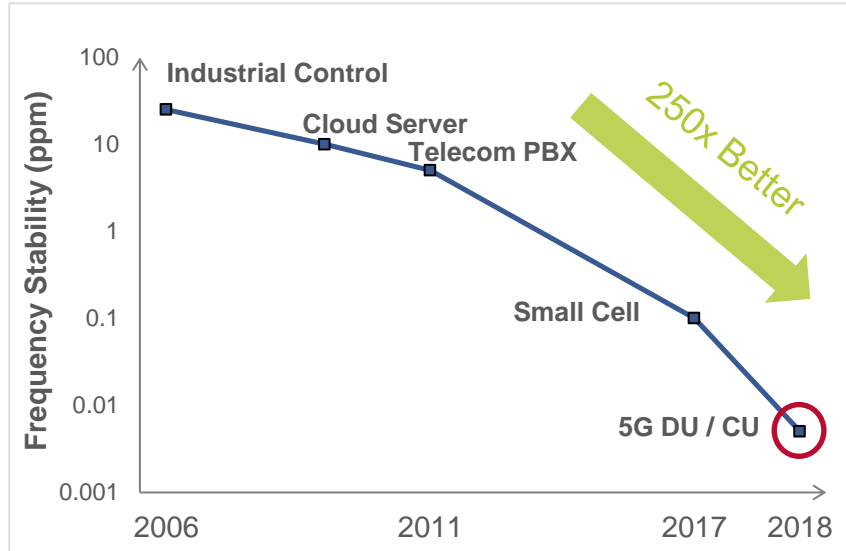
90% Lower Power  
70% Lighter  
40% Thinner



2017

20x More Robust  
30x More Accurate  
30x More Reliable

# Rapid Innovation of Past Decade Will Continue into the Future



# Drivers for SiTime's Target Markets



## 5G – \$2 Trillion Network Upgrade

- Real-time services - 100x more bandwidth
- Densification - 10x radios, high stress environment (vibration, airflow, high temperature)



## Mobile-IoT – Internet Everywhere

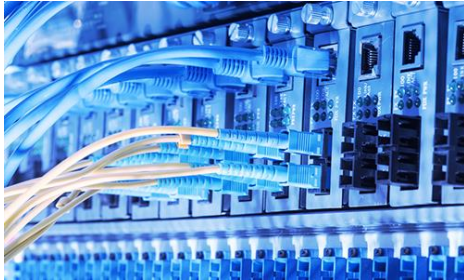
- Tiny, battery-powered, lightweight end points
- 10 year reliability



## Automotive – Networking the Car

- Supercomputer, AI, All Around Sensing
- High stress – shock, vibration, temperature

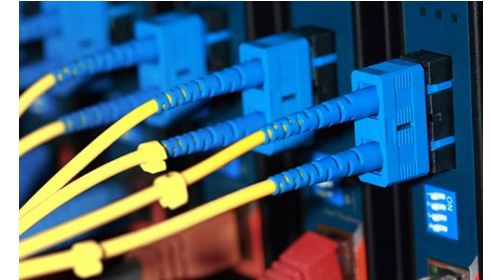
# SiTime's Success in Communications



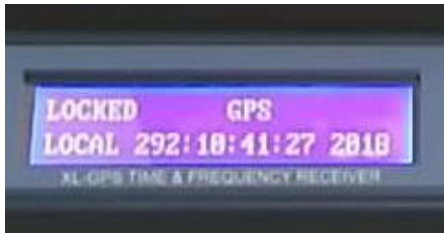
Routers, Switches, OTN



4G+/5G RRH, DU, CU



Cable Headend / Remote PHY



Timing Servers



Satellite Broadband

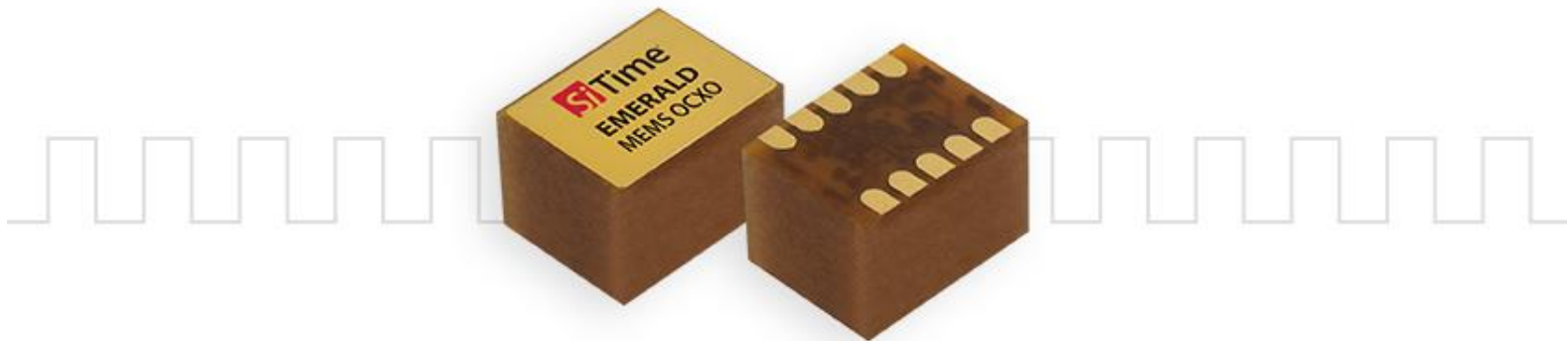


100G/400G SFP Module



# Emerald Platform™

## ±5 ppb MEMS OCXO



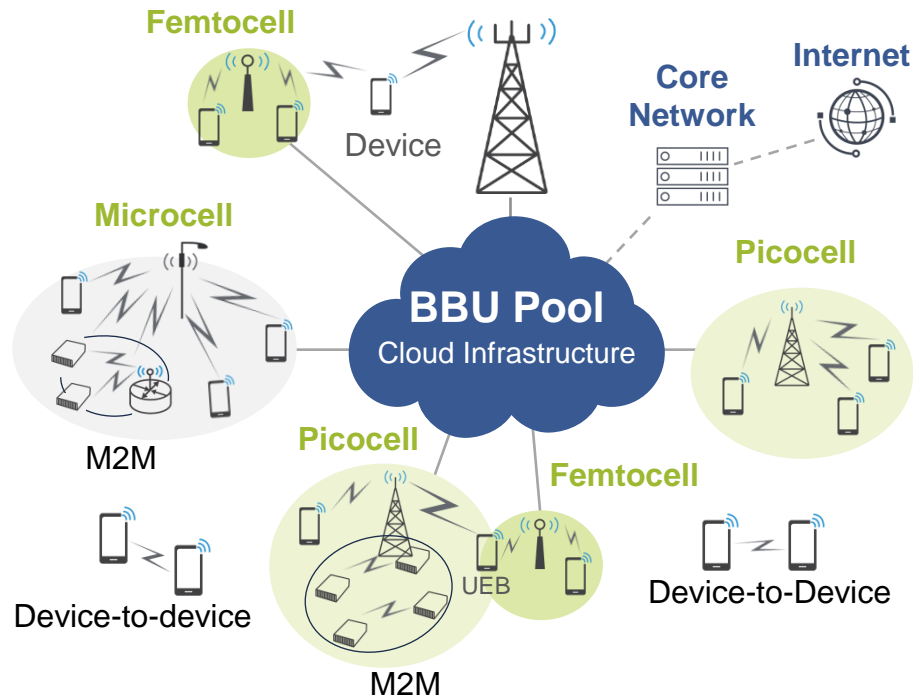
## The Most Robust Timing Solution for 5G



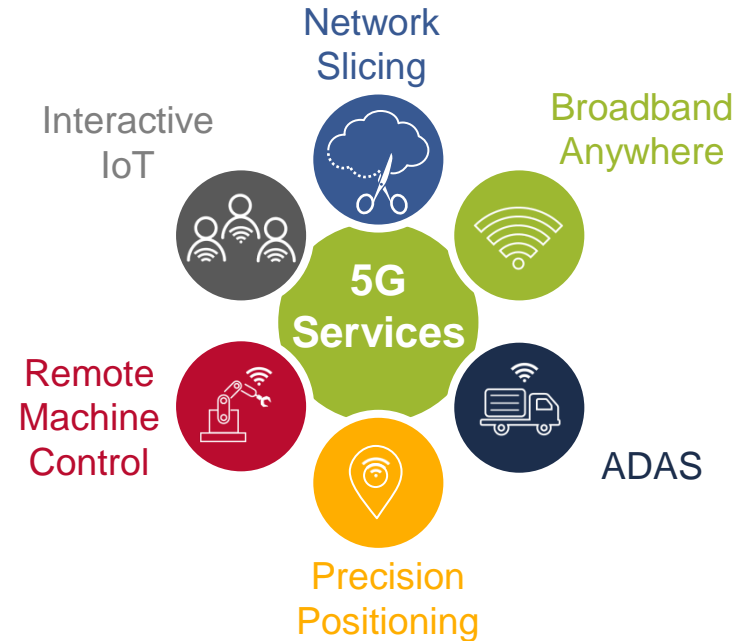
# Precision Timing is the Heart of 5G Infrastructure

## 5G Architecture

More Radios Closer to Consumer



New, Mission Critical Services



# 130 nano-seconds

Radio-to-radio time accuracy under all conditions

Required for 5G service success

ITU Q13/15 "Network Synchronization and time distribution performance Supporting 5G mobile transport and fronthaul" recommendations

# Stable and Reliable Timing Needed for 5G Services



## Operator Needs

**Network  
Slicing**

**Mission Critical  
Services**

**Deployment  
Anywhere**

**Zero  
Downtime**

## Impact of Timing

**130 nano-seconds Radio-to-Radio Accuracy**

Minimizes spectral interference  
Maximizes bandwidth

**Clock Cannot Fail**

Highest reliability - No “Activity dips”,  
Immune to shock, vibration, temperature

**Simple, Small System**

Operate at high temperature  
Immune to shock, vibration, temperature  
Small clock size, low power

**Consistent Clock Performance**

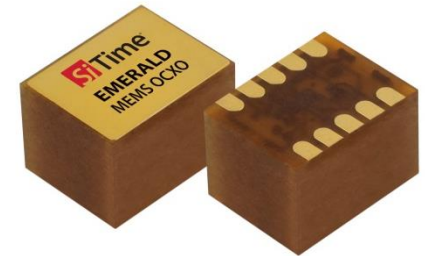
Immune to transients - shock, vibe, temperature  
Performance does not change over time

Operator Needs Reference: 3GPP Mobile Broadband Standard – Release 15

# Emerald MEMS OCXO – 9x7mm, 75% Smaller, Stratum 3E Compliant



- Best stability under airflow or thermal shock
  - $\pm 5$  to  $\pm 50$  ppb over-temp stability
  - $\pm 50$  ppt/ $^{\circ}\text{C}$  typical frequency slope ( $\Delta F/\Delta T$ ), 10x better than quartz OCXO
- Robust operation under any conditions
  - Vibration resistant,  $\pm 0.1$  ppb/g, 20x better than quartz OCXO
  - $-40$  to  $+85^{\circ}\text{C}$  operating temperature now,  $-40$  to  $+105^{\circ}\text{C}$  in near future
- Game-changing ease of use
  - Can be placed anywhere on the PCB
  - No covers needed to isolate from thermal shock and airflow
  - No external regulator, on-chip power supply noise filtering
  - Resistant to high humidity
- Most flexibility
  - Programmable frequency from 1 to 220 MHz
  - LVCMOS or clipped sine wave outputs
  - In-system configurability through I2C in near future



# Emerald Meets 5G Deployment Challenges



Equipment Condition	Problem	Emerald Solution
Outdoor deployment	High ambient temperatures	Up to +105°C operation
Cooling fans	Generate rapid change in temperatures – thermal shock	Excellent dynamic stability, 50 ppt/°C
Pole mounted systems	Subject to vibration	0.1 ppb/g vibration immunity
Deployment in tropical areas	High humidity	Resistant to high humidity

# Emerald MEMS OCXOs are Easy to Use



Design Consideration	Emerald Stratum 3E	Quartz OCXO
Thermal isolation	Not needed	Metal or plastic cover needed
PCB placement	Anywhere	Must be placed away from airflow and heat source
Power supply	On-chip regulation	Needs external LDO or filter
Signal integrity	Can be placed close to SOC	Far from SOC, long signal traces on board
Manufacturability	Handles high humidity	Prone to leakage resulting in failure
Small size	9 x 7 mm	20 x 13 mm
Availability	Semiconductor supply chain, always available	Custom built. Long lead times, minimal flexibility
Quality	Consistency, no batch to batch variations	Batch to batch variations

# Emerald Product Offerings

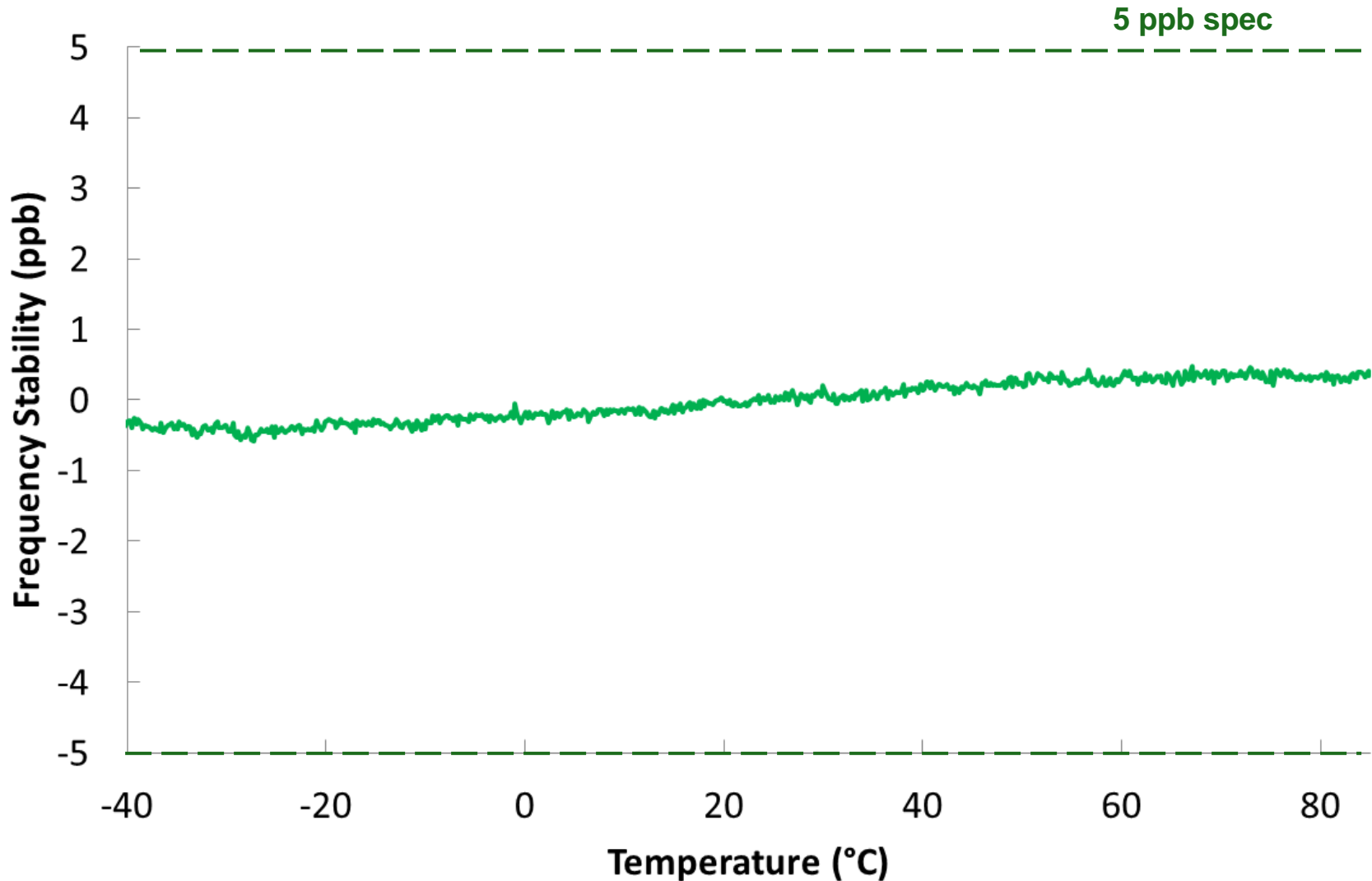


Category	Part #	Frequency (MHz)	Stability (ppb)	I <sup>2</sup> C	Package (mm)	Availability
<b>Precision Sync Oscillator</b>	SiT5701	1 to 60	$\pm 15$ to $\pm 50$	No	9 x 7	Samples 2Q 2019
	SiT5702	60 to 220				Production 3Q2019
<b>Stratum 3E OCXO</b>	SiT5711	1 to 60	$\pm 5$ to $\pm 10$	No	9 x 7  Additional: 14 x 9, 25 x 22 (common footprints)	Samples Now
	SiT5712	60 to 220				Production 2Q2019
<b>Digitally Controlled Stratum 3E OCXO</b>	SiT5731	1 to 60	$\pm 5$ to $\pm 10$	Yes	9 x 7	Samples 2Q 2019
	SiT5732	60 to 220				Production 3Q2019

Common features: -40 to 85°C, 3.3V.

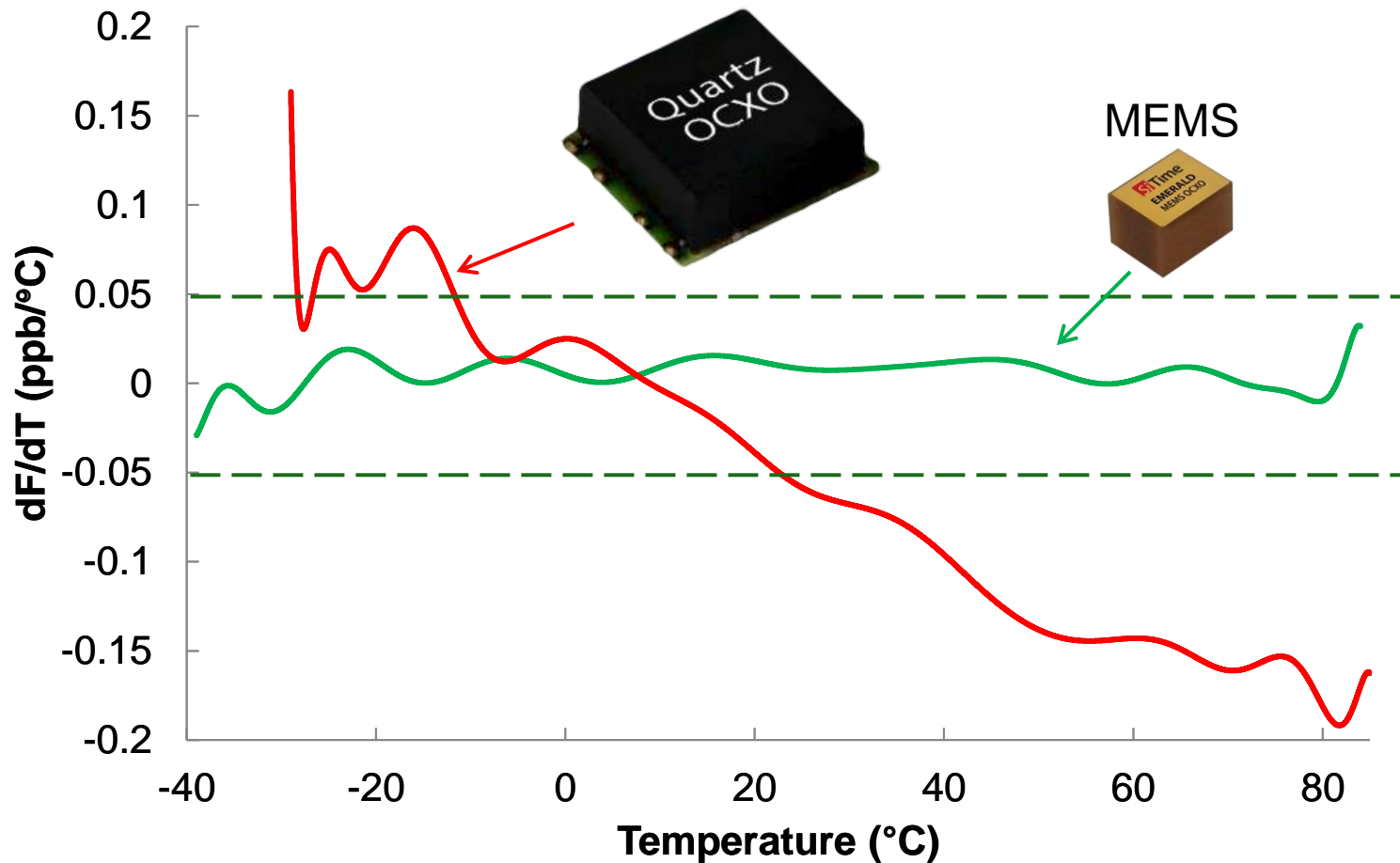
Future options (2019): -40 to 105°C, I<sup>2</sup>C

# Emerald Demonstrates $\pm 1$ ppb Stability, Adequate Margin for $\pm 5$ ppb Spec

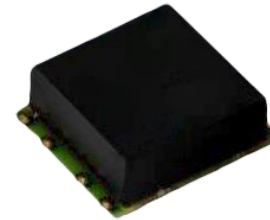
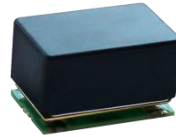




# Emerald 10x Better in $\Delta F/\Delta T$ , Meets 5G Radio-Radio Time Accuracy Requirement

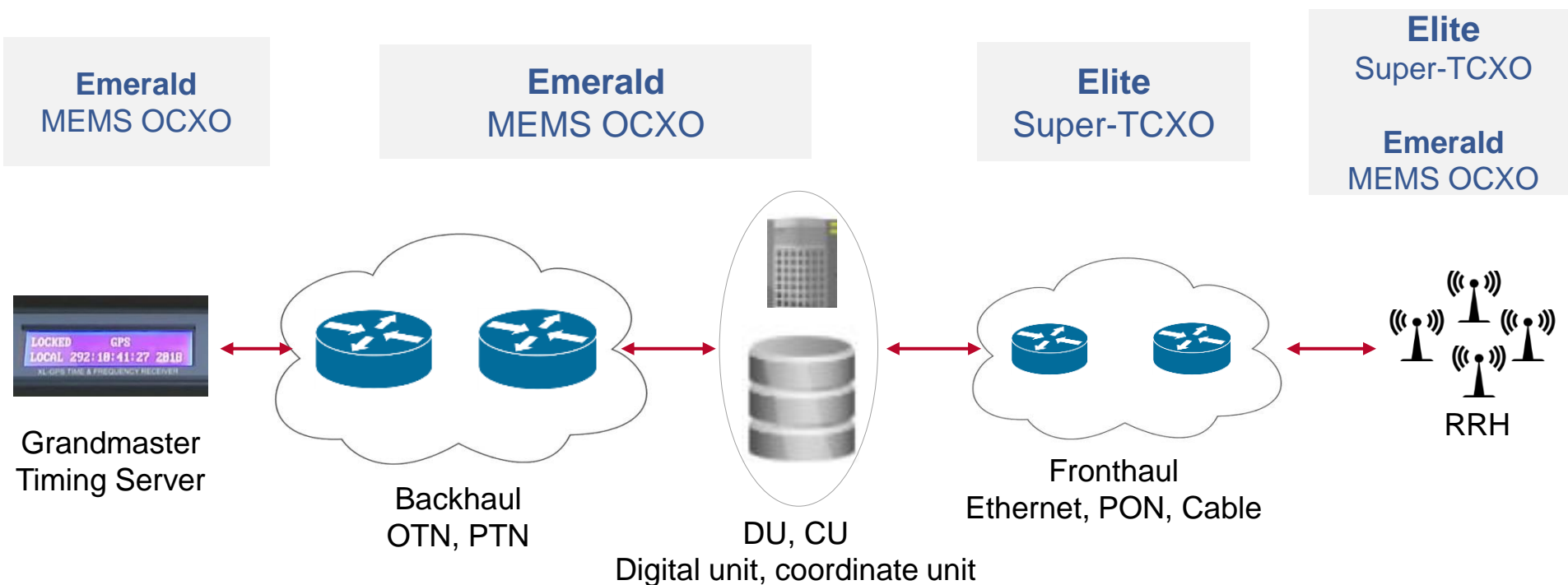


# Emerald Advantages Over Legacy Quartz Stratum 3E OCXOs



Parameter	Emerald	Quartz OCXO 1	Quartz OCXO 2	Quartz OCXO 3
Size	9 x 7 mm	20.7 x 13.1 mm	25 x 22 mm	25 x 22 mm
Stability over Temp	±5 ppb	±5 ppb	±10 ppb	±10 ppb
Active Power	0.65 Watts	1 Watt	1.5 Watts	≤ 1.5 Watts
Temperature Range	-40°C to 85°C now -40°C to 105°C soon	-40°C to 95°C	-40°C to 85°C	-40°C to 85°C
Daily Aging	±0.8 ppb / day	±1 ppb / day	±1 ppb / day	±0.5 ppb / day
Long Term Aging	±500 ppb / 20 years	±1 ppm / 10 years	±100 ppb / year	±800 ppb / 20 years
Warm Up Time	2 min	3 min	5 min	≤5 min
Health Monitoring Through I <sup>2</sup> C	Future	No	No	No
Reliability	Good	Fragile	Fragile	Fragile

# SiTime for Every 5G Network Node



## SiTime Provides

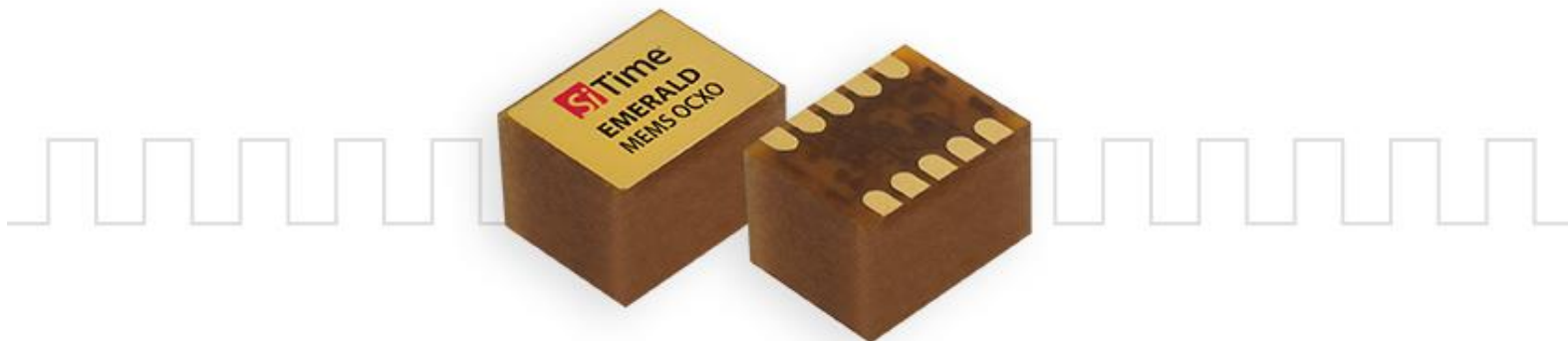
**Complete timing solutions** – Quartz free, scalable, guaranteed performance

**Up to 20x better dynamic performance** – vibration, thermal shock, airflow & heat resistant

**Most features and flexibility** – any frequency, +105C operation, in-system programmable

# Emerald Platform™

## ±5 ppb MEMS OCXO



## The Most Robust Timing Solution for 5G

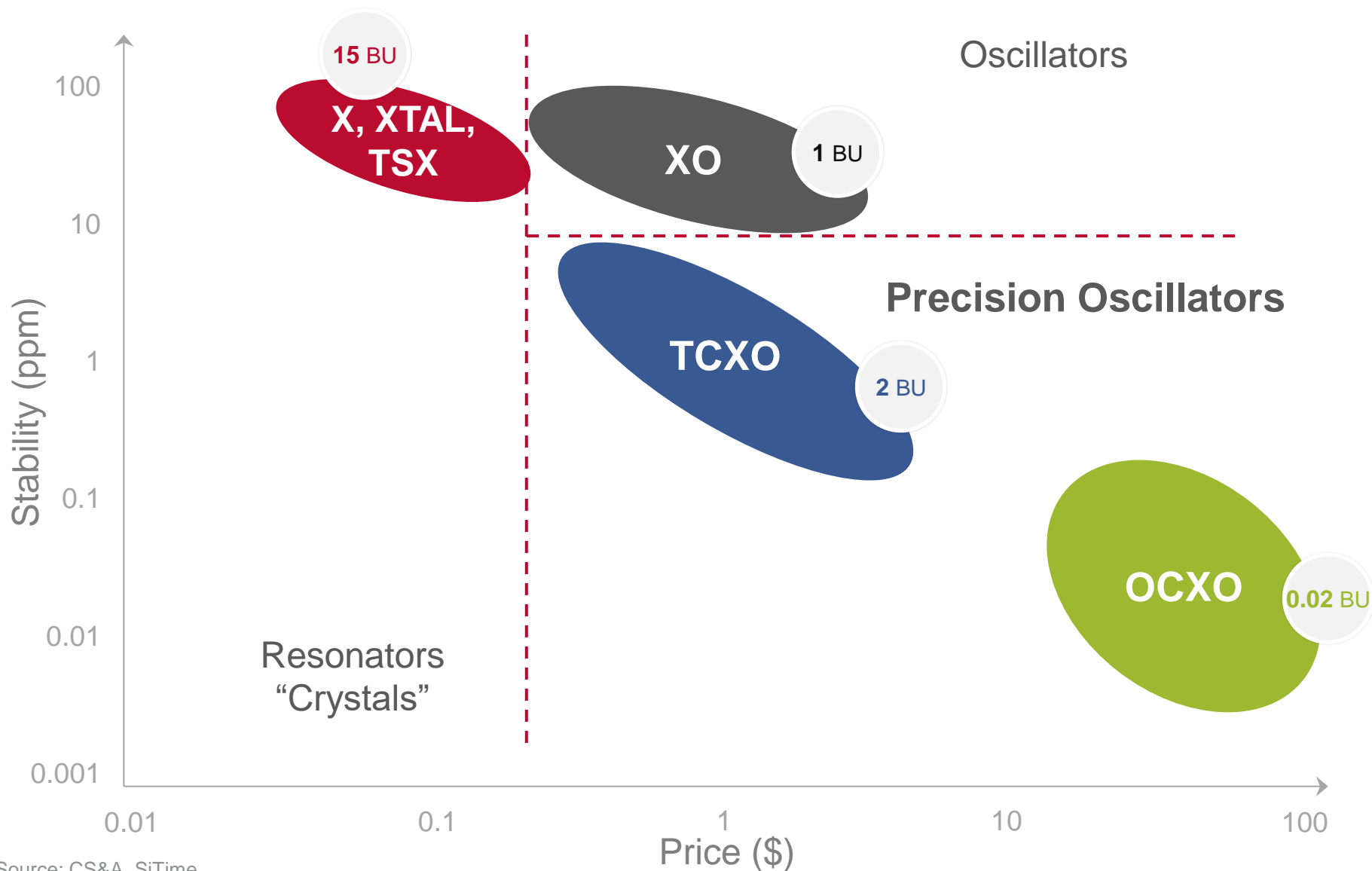


## Additional Information

October 2018

# Resonator & Oscillator Market

Stability, Price, Annual Volume



Source: CS&A, SiTime

# Comparison of Resonator & Oscillator Timing Products



Product Type	kHz or MHz	Stability (PPM)	Market Price	SiTime
<b>XTAL</b> (Resonator)	Both	20 - 100	\$	--
<b>XO / SPXO</b> (Oscillator)	Both	10 - 100	\$\$	Now
<b>VCXO</b> (Voltage Controlled Oscillator)	MHz	10 - 100	\$\$\$	Now
<b>Mobile TCXO</b> (Temperature Compensated Oscillator)	MHz	0.5 - 2.5	\$\$	--
<b>Infrastructure TCXO</b> (Temperature Compensated Oscillator)	MHz	0.1 - 0.28	\$\$\$\$	Now
<b>Super-TCXO</b> (TCXO with best dynamic stability)	Both	0.1 - 5	\$\$\$\$	Now
<b>OCXO</b> (Oven Controlled Oscillator)	MHz	0.001 - 0.05	\$\$\$\$\$	Now

Stability / Accuracy – Lower PPM is Better



# Oscillator Types & End Applications



Oscillator Type	Special Function	End Applications
<b>XO or SPXO</b>	N/A	Everywhere a clock is needed (consumer, industrial, etc.)
<b>VCXO</b>	Output fine-tuned by up to 3600ppm	Clock synchronization in telecom, broadband, video & instrumentation
<b>Mobile TCXO</b>	N/A	Mobile phone, tablet, data cards, wearables
<b>Super VCTCXO / TCXO</b>	Dynamic performance	5G Edge, High performance equipment, networking, industrial GPS, satellite, SyncE, microwave backhaul
<b>OCXO</b>	Oven-controlled, ultra low noise	5G Core and Edge, High performance equipment, industrial GPS, satellite, IEEE1588, SONET
<b>SSXO</b>	Spread %	Reduce EMI in system – industrial, office automation, consumer
<b>DCXO</b>	Digital control	Replaces VCXO, control via I2C / SPI
<b>FSXO</b>	Pin-selectable Frequency	Low volume, high mix, BOM reduction
<b>ISPXO</b>	I2C/SPI programmable	Prototyping, low volume, high mix