DECADES OF MEMS TIMING

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ABSTRACT

As quartz-based oscillators reach their centennial, and MEMS-based oscillators approach their second decade, the younger technology is surpassing the performance of its predecessor. The latest generation of MEMS-based temperature-compensated oscillators achieve ±5 ppb frequency stability over -40 to 105 °C, enabling them to replace miniature oven-controlled crystal oscillators (mini-OCXOs). Ovenized MEMS-based oscillators, including SiTime's recently announced Epoch line, exceed the performance of traditional OCXOs and encroach into the territory of chip-scale atomic clocks (CSACs). Along with part-per-billion level frequency stability, these MEMS-based oscillators offer dramatic improvements in pricing, mechanical robustness, power, size, reliability, and manufacturing scalability.

KEYWORDS

Timing, stability, MEMS, resonator, oscillator, TCXO, OCXO

INTRODUCTION

MEMS-based oscillators have been temperature-compensated since commercialization by necessity, as the native frequency-temperature stability of early MEMS resonators was too poor to be marketable without correction. Subsequent improvements in the MEMS reference resonator, the temperature sensor, packaging, and compensation circuitry have all contributed to tightening the frequency stability of MEMS-based TCXOs by 4 orders of magnitude over less than two decades (see Figure 1).

More recently, MEMS-based oscillators have borrowed from quartz-based OCXOs. The resonator and temperature-sensitive oscillator circuitry are placed in a temperature-controlled oven and maintained at a stable temperature above ambient to minimize temperature-induced frequency variation. This enables MEMS-based OCXOs to build on the performance of MEMS-based TCXOs.

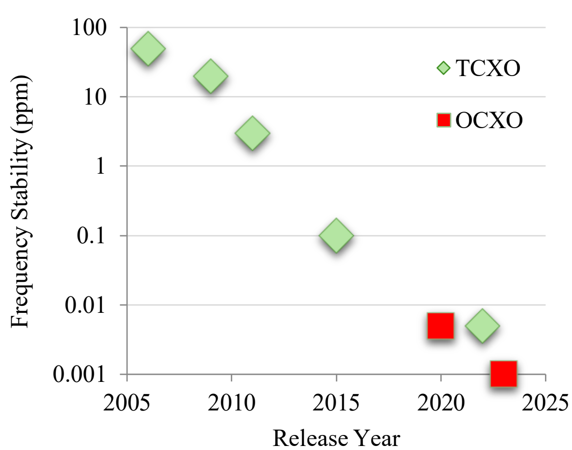

Figure 1: The frequency stability of MEMS-based oscillators has improved 50,000x in less than 20 years.

Table 1: Properties of SiT550x (Elite X Super-TCXO) benchmarked against conventional mini-OCXOs from two manufacturers.

	Super-TCXO SiT550x	**Mini-OCXO B**	**Mini OCXO C**
Resonator Type	MEMS	Quartz	Quartz
Heater	No	Yes	Yes
Size (mm x mm x mm)	7x5x2	10x7x4	10x7x4
Power (mW)	110	400	650
Maximum Temperature (°C)	105	95	95
Frequency Stability (ppb)	5	10	20
Stability Slope (ppb/°C)	0.3	0.5	2
Initial Tolerance (ppb)	100	200	200
Daily Aging (ppb)	0.3	1	5
10-year Aging (ppm)	< 0.15	2	1.5
Warm-Up Time (sec)	< 1	15	> 180

RESULTS

When benchmarked against mini-OCXOs, SiTime's Elite X Super-TCXOs show 2-4x superior frequency stability over temperature, 2x lower initial tolerance in frequency, 3x less daily aging and 10x less long-term aging with quicker warmup, smaller size, and lower power. Results are summarized in Table 1. This new class of MEMS-based TCXOs can be used in applications that previously called for OCXOs.

In Figure 2, Epoch MEMS OCXOs exhibit frequency stability within ±0.2 ppb from -40 to +90 °C. Similar to Elite X, Epoch outperforms quartz OCXOs and even CSACs on multiple axes.

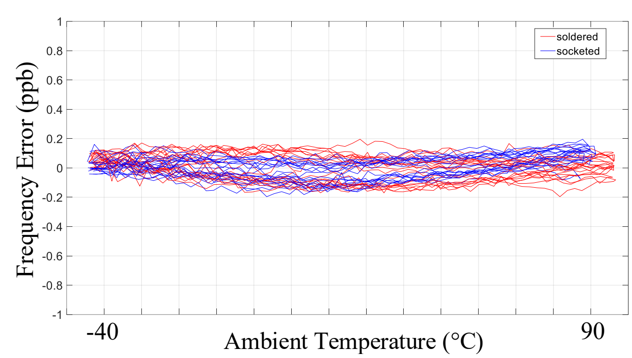

Figure 2: Frequency stability over temperature of several Epoch (MEMS OCXOs) both before and after soldering down (n=10).

CONCLUSIONS

MEMS-based oscillators have come into their own with ppb-level frequency stability over temperature and a compelling suite of advantages over traditional quartz-based timing products.

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