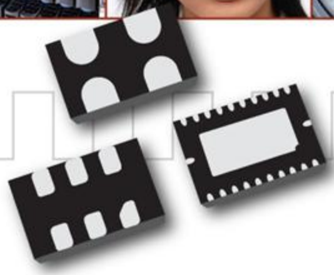
Delivering Stable Timing Under Harsh Real-World Environmental Conditions with High-Precision 100-ppb TCXO



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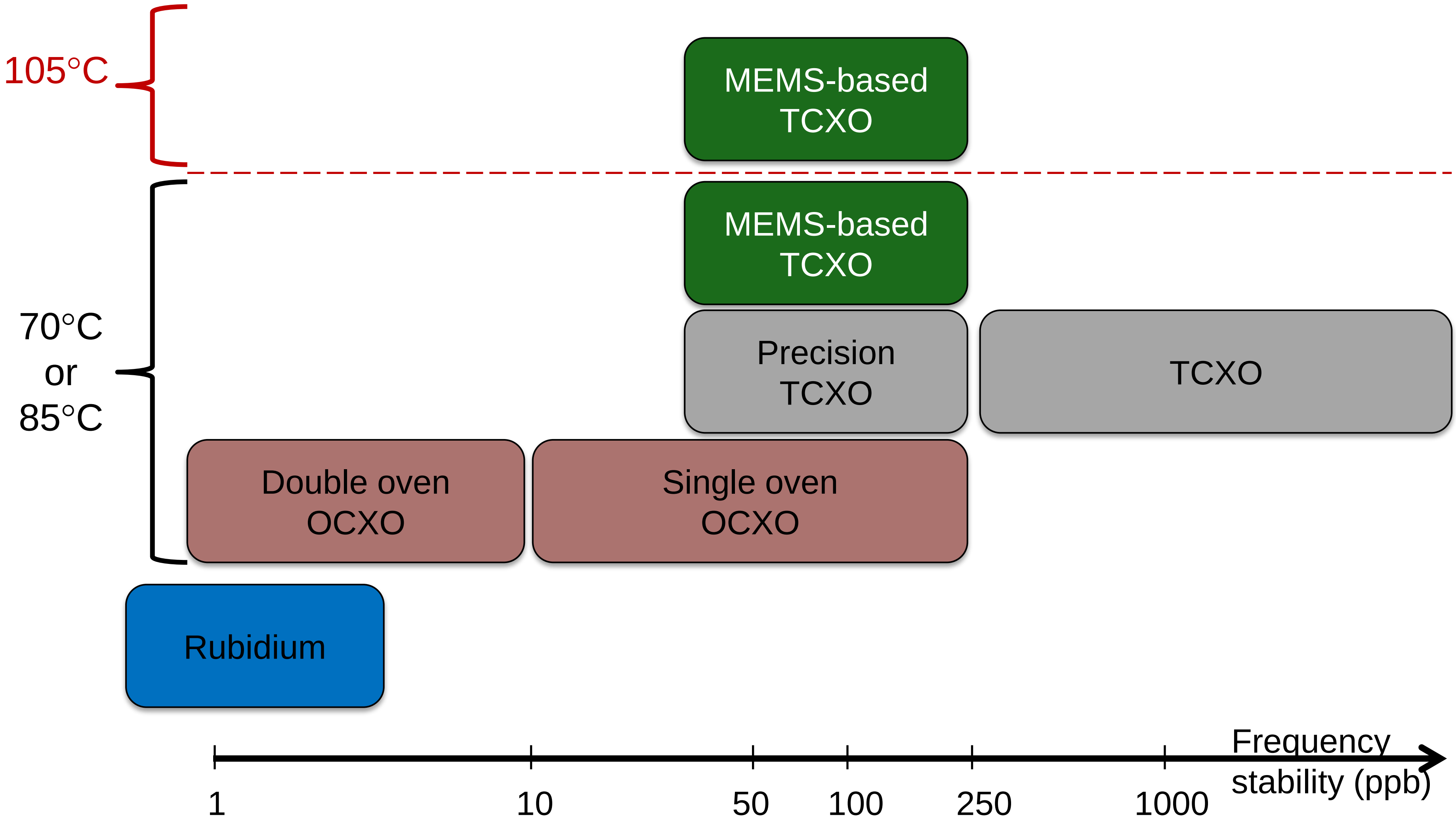
The Smart Timing Choice™

Outline

- Introduction
- Precision MEMS-Based Temperature Compensated Oscillator (TCXO) architecture
- Performance data
- Conclusions

Introduction



Applications

- Stratum-3: GR1244 compliant
- SyncE
- IEEE1588
- Small Cell / Femtocell
- Industrial GPS

MEMS-Based TCXO Target: Precision Timing Under All Conditions

SiTime™

Stability

- Temperature range
- Temperature ramp
- Activity dips
- Freq. slope over temperature
- VDD / Load

Short Term Stability

- ADEV
- Wander (MTIE / TDEV)
- Still air and in airflow

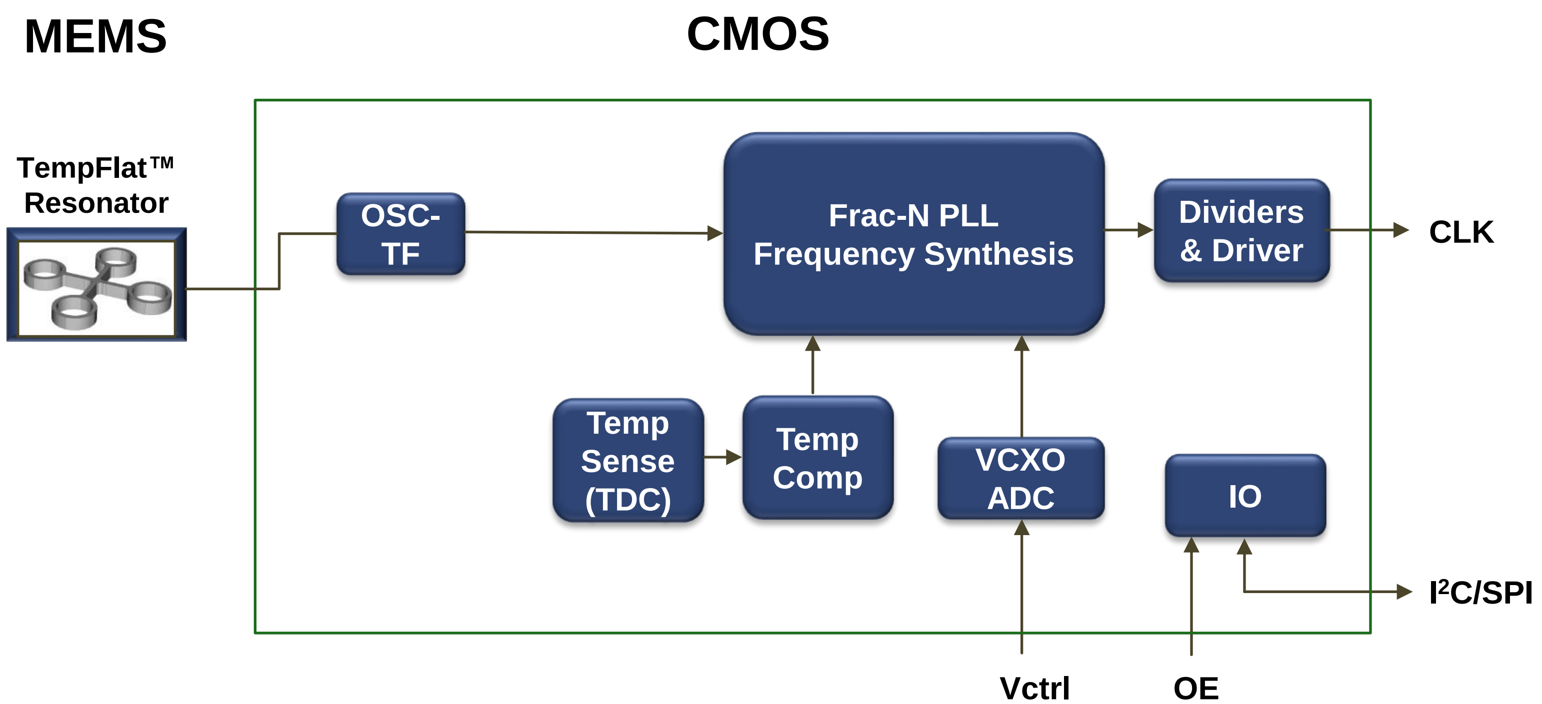
Robustness

- Vibration
- Shock
- PSNR

Flexible Feature Set

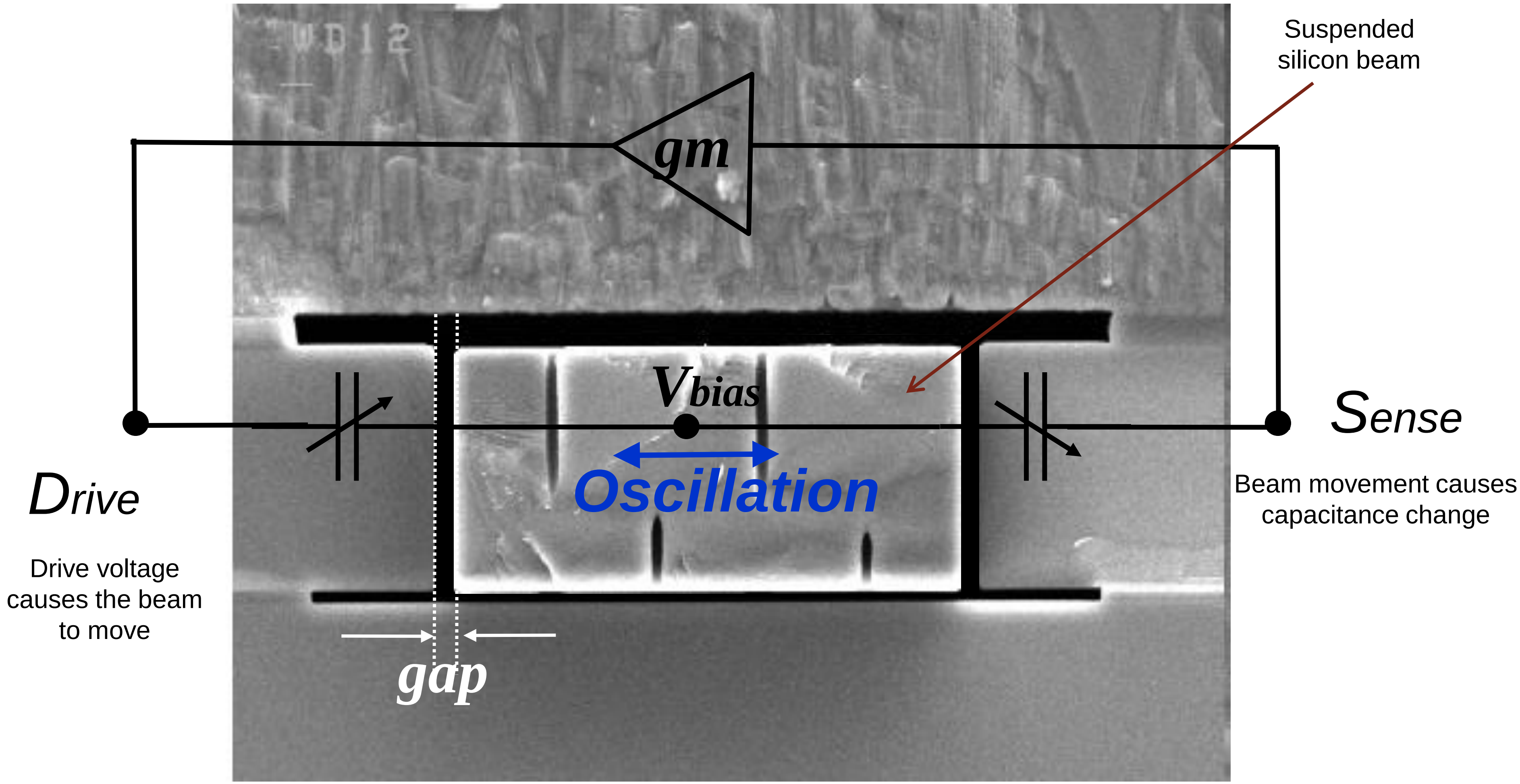
- Frequency range
- Differential output
- Digital frequency control

MEMS-Based Precision TCXO Architecture



- Fractional-N synthesizer for frequency control
- High bandwidth low noise temperature sensing for fast temperature tracking without phase noise degradation

Sustaining Circuit
Vibrating Resonator Principle

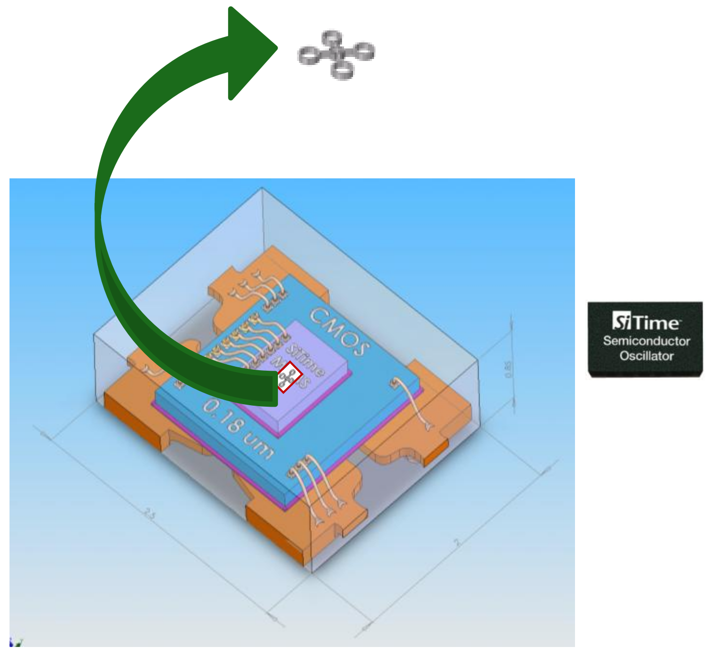


Electrostatic MEMS is free of activity dips

Single-Anchor MEMS Resonators: Robust Against Shock & Vibration

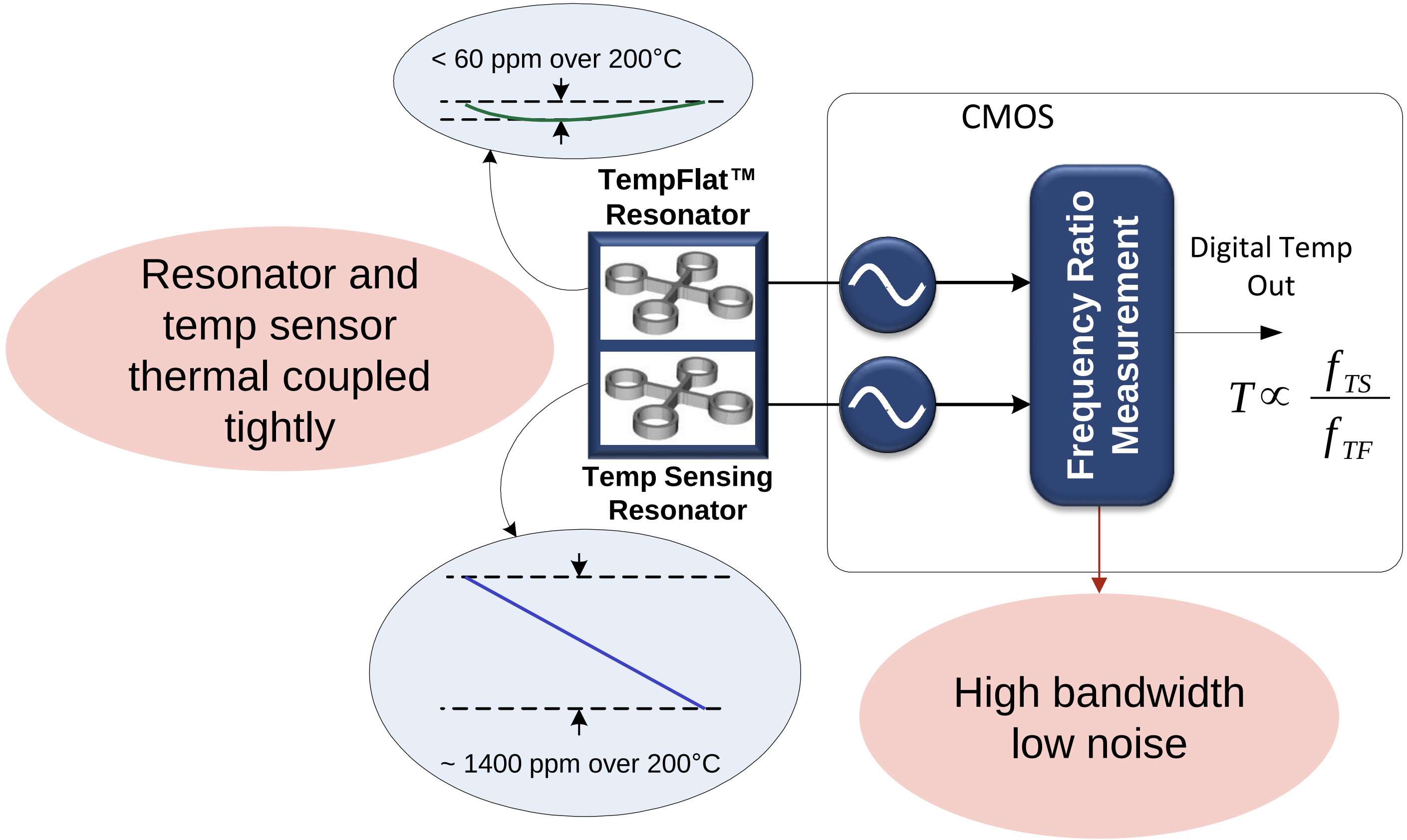
- Resonator mass is extremely small and stiff → Large acceleration needed to move mass
- MEMS resonator mass is 1000 to 3000 times smaller than quartz

Silicon MEMS Resonator Mass
Independent of Package and frequency

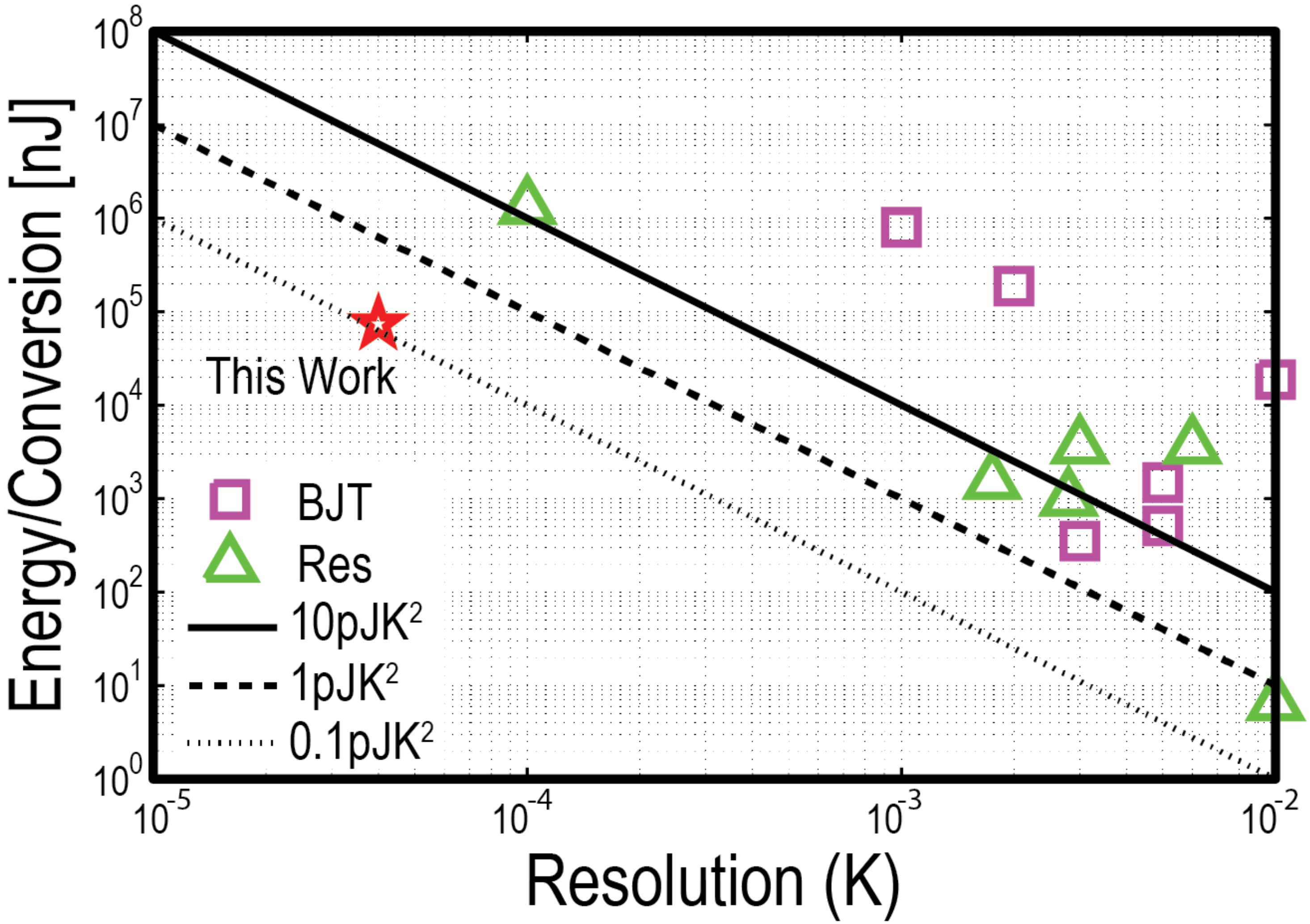


Dual MEMS Resonator Temperature Sensing

- < 30 µK resolution in 100 Hz bandwidth
- Temp sensor phase noise < oscillator phase noise → Noise-less temperature compensation



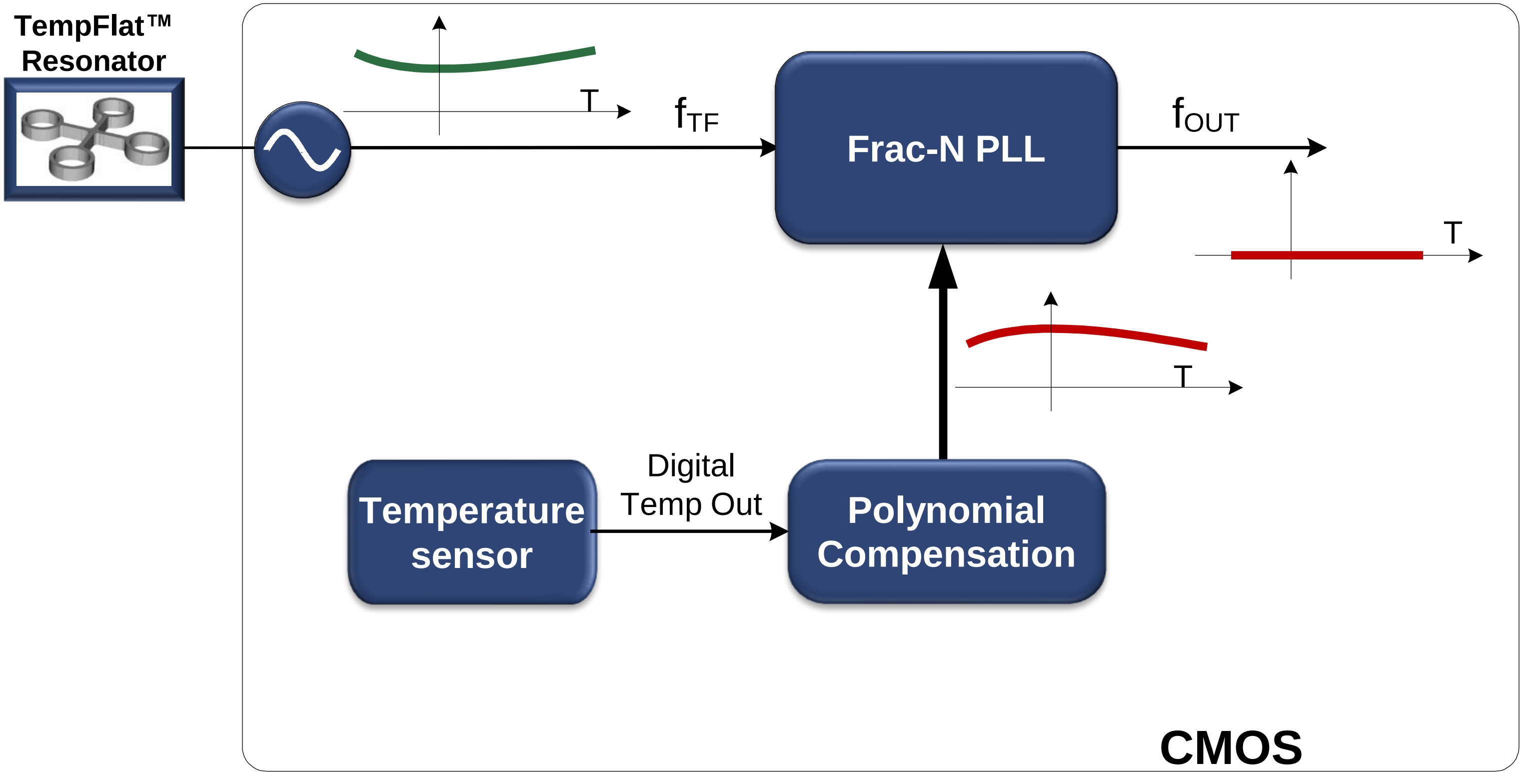
Dual MEMS Resonator Yields Highest Figure of Merit



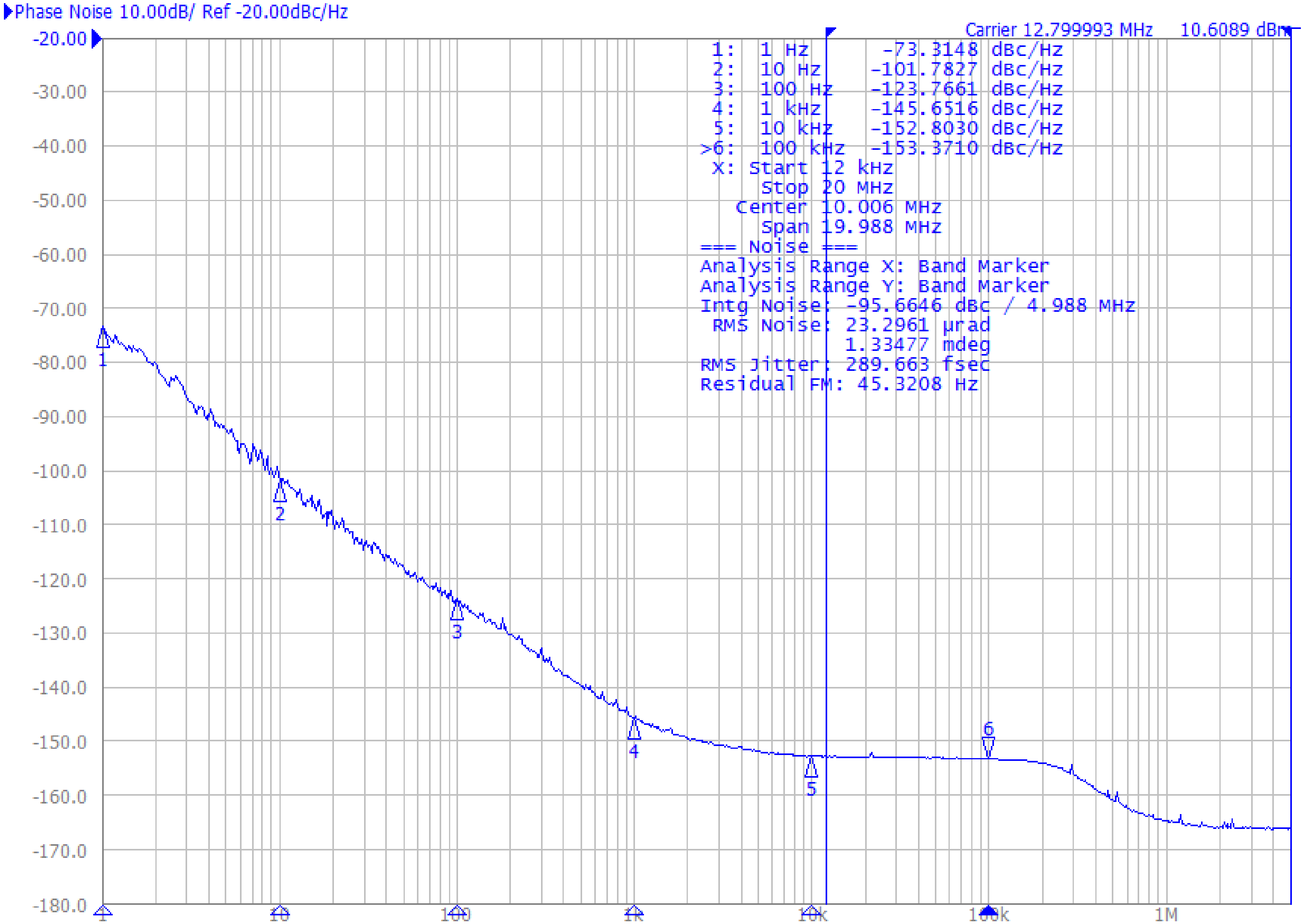
Res. FOM = (Energy/Conversion)×Resolution^2

High-BW Temperature Compensation: Key to Precision TCXO in thermally noisy environment

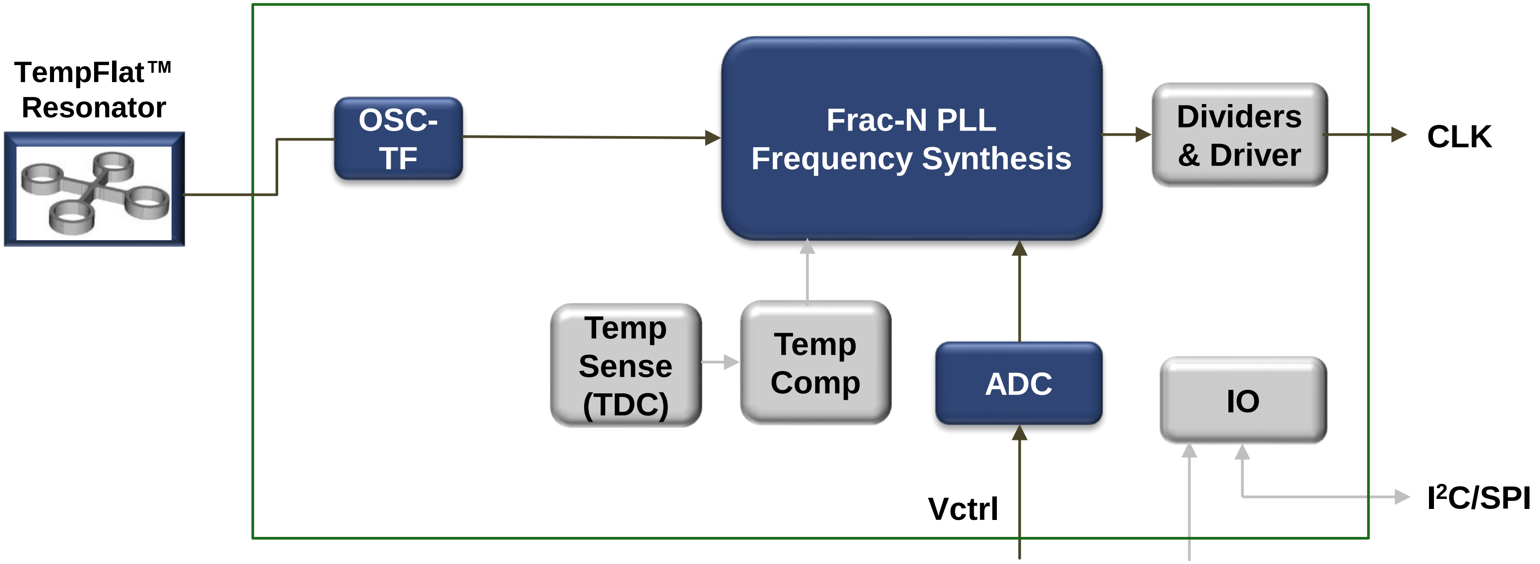
- MEMS-based TCXO Temperature tracking BW up to 350 Hz, 40x faster than best-in-class TCXO
- Tracks fast temperature fluctuations (fans, heating due to chipset proximity)
- Noiseless Temperature compensation: No additional phase noise from temp comp



MEMS-Based TCXO Phase Noise



Voltage Control for MEMS-Based VC-TCXO

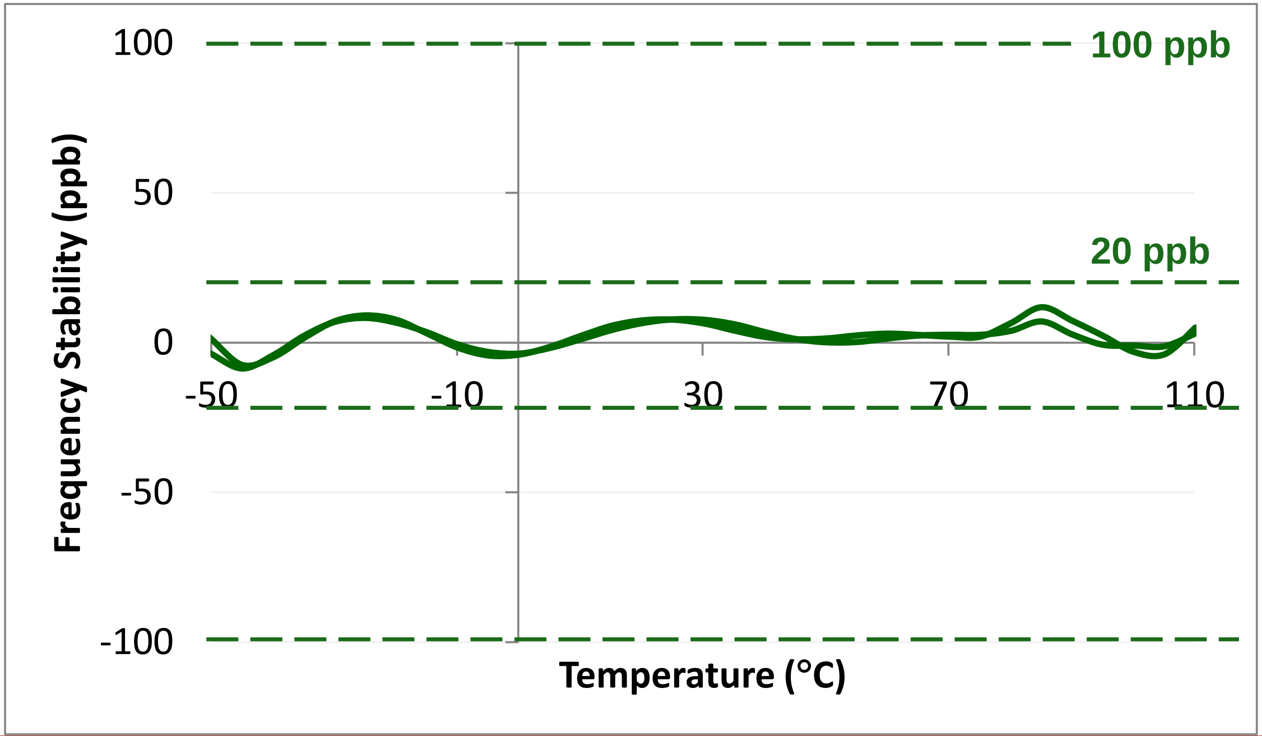


- PLL-based frequency pull
- Highly linear characteristics across full Vctrl range: < 0.1%
- Highly consistent VCXO frequency control gain: < 10%
- f-vs-T degradation due to Vcntrl: ~ ±10ppb across full Vctrl range
- Low noise ADC for low phase noise performance
- Wide pull range selection: ±6.25 ppm to ±50 ppm
- Factory programmable Vctrl bandwidth: 5 kHz to 40 kHz

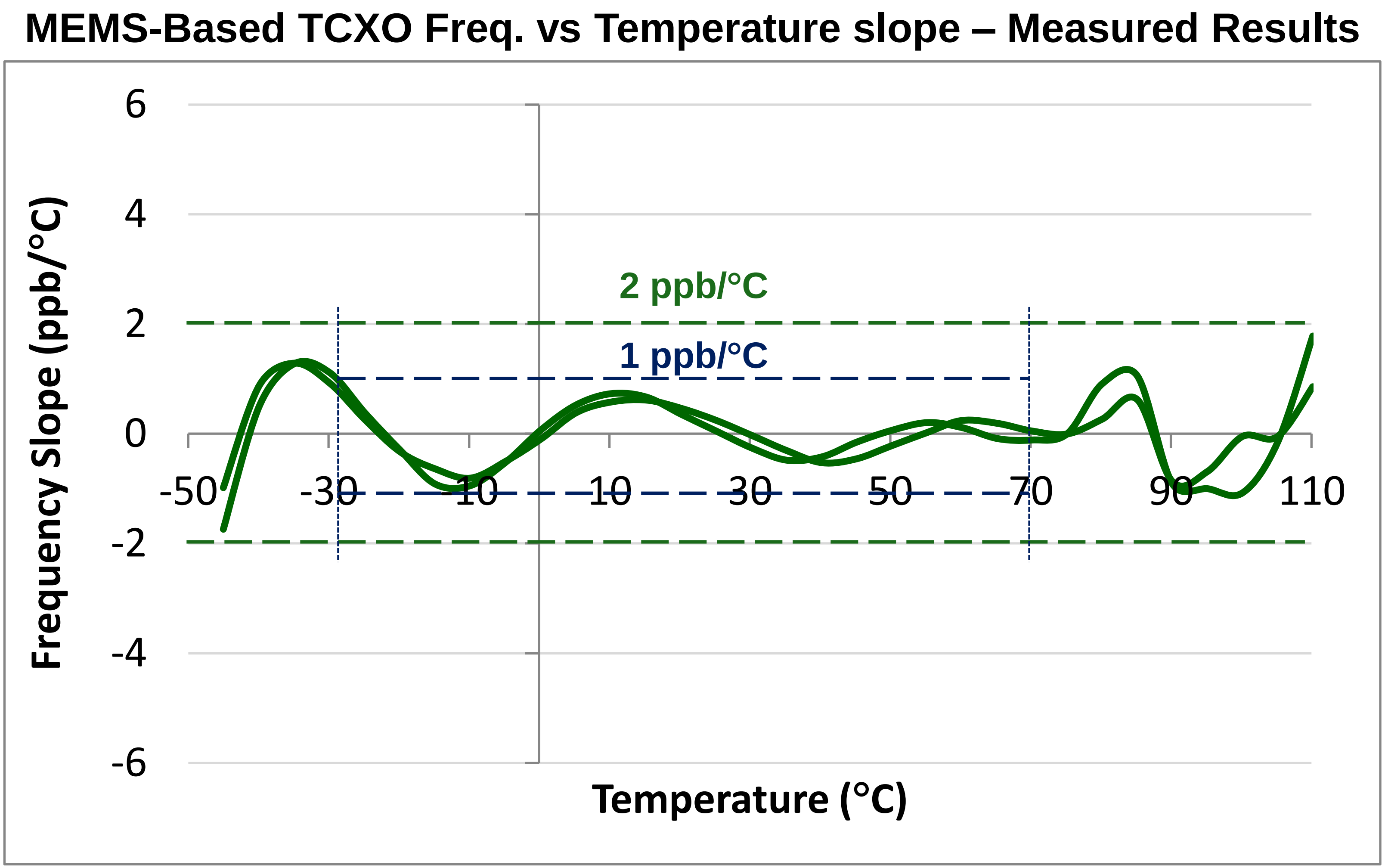
Temperature Stability: ±100 ppb up to 110ºC

Specification	MEMS TCXO	Quartz TCXO
Frequency Stability	±100 ppb	±100 ppb
Temperature range	-40°C to +105°C	-40°C to +85°C
Max temperature ramp rate	10°C/min	1°C/min

MEMS-Based TCXO Frequency Stability – Measured

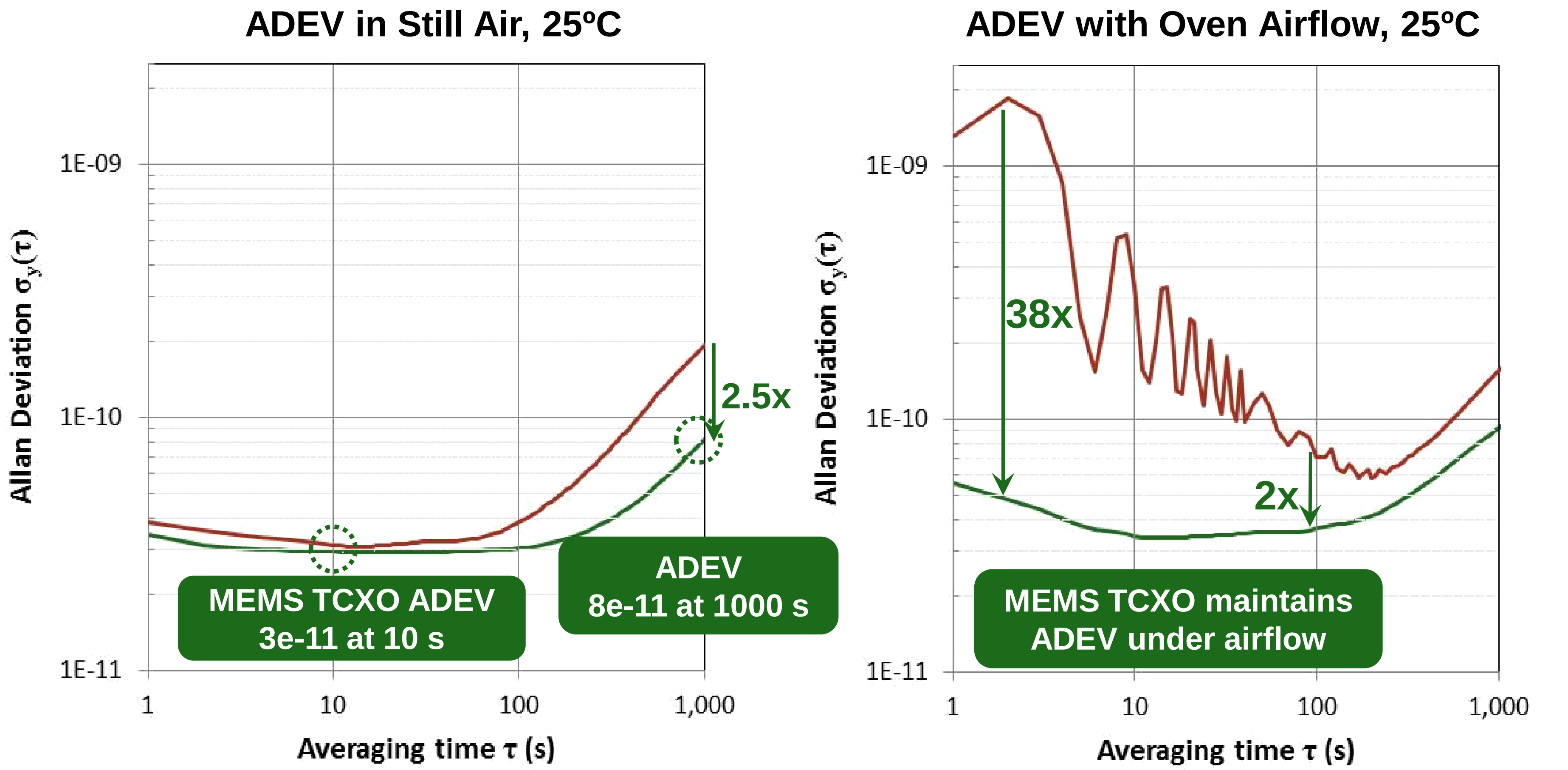


Frequency Slope vs. Temperature for IEEE 1588



ADEV in Airflow Conditions

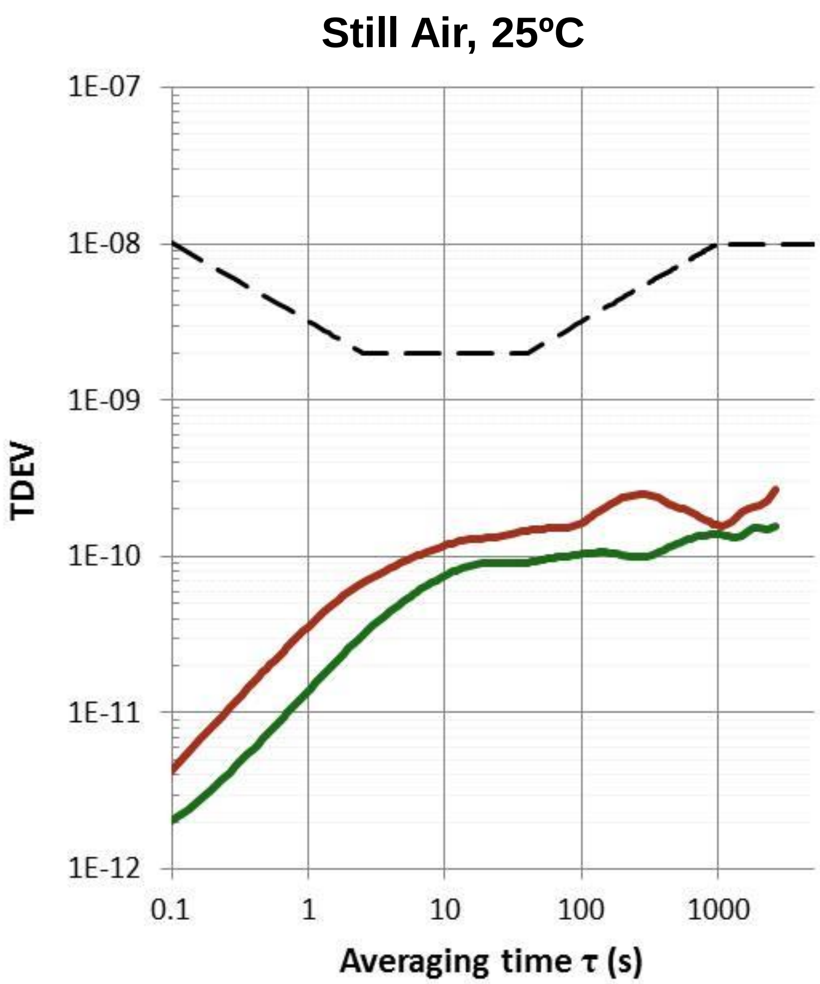
SiTime™

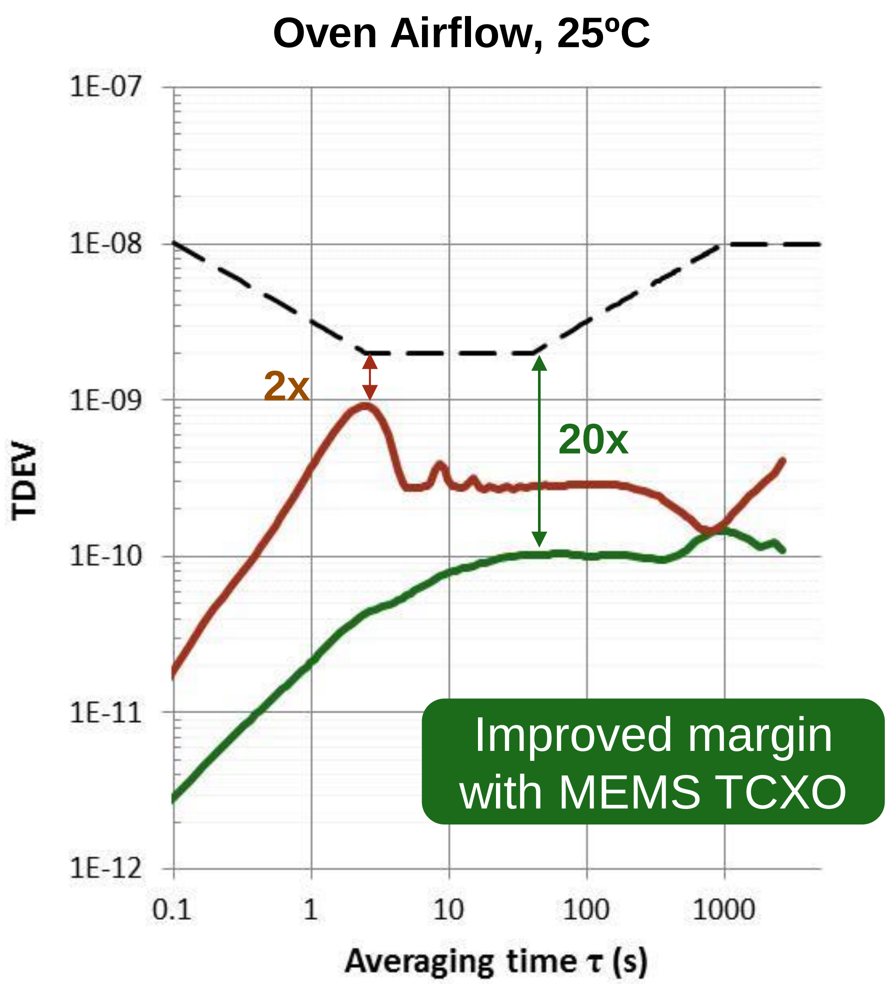


MEMS-Based TCXO: 20 MHz, ±100 ppb, -40ºC to 85ºC

Quartz TCXO: 10 MHz, ±50 ppb, -5ºC to 70ºC

ITU-T G.8262-Compliant TDEV Under Still Air and Airflow Conditions

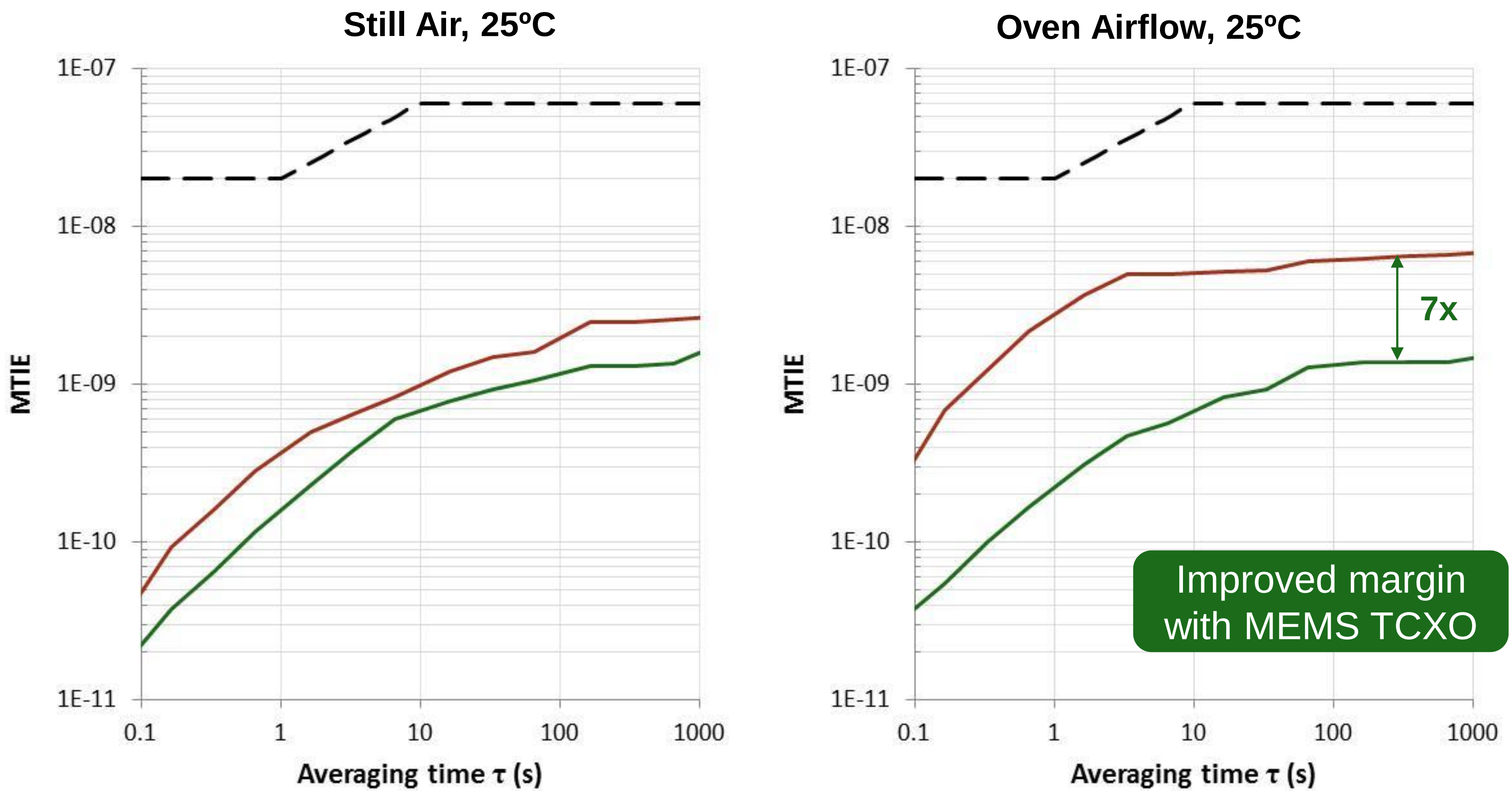




- - Compliance Mask
— MEMS-Based TCXO: 20 MHz, ±100 ppb, -40ºC to 85ºC
— Quartz TCXO, 40 MHz

Measured on SiLabs demo board Si5328-EVB
with 88 mHz PLL setting

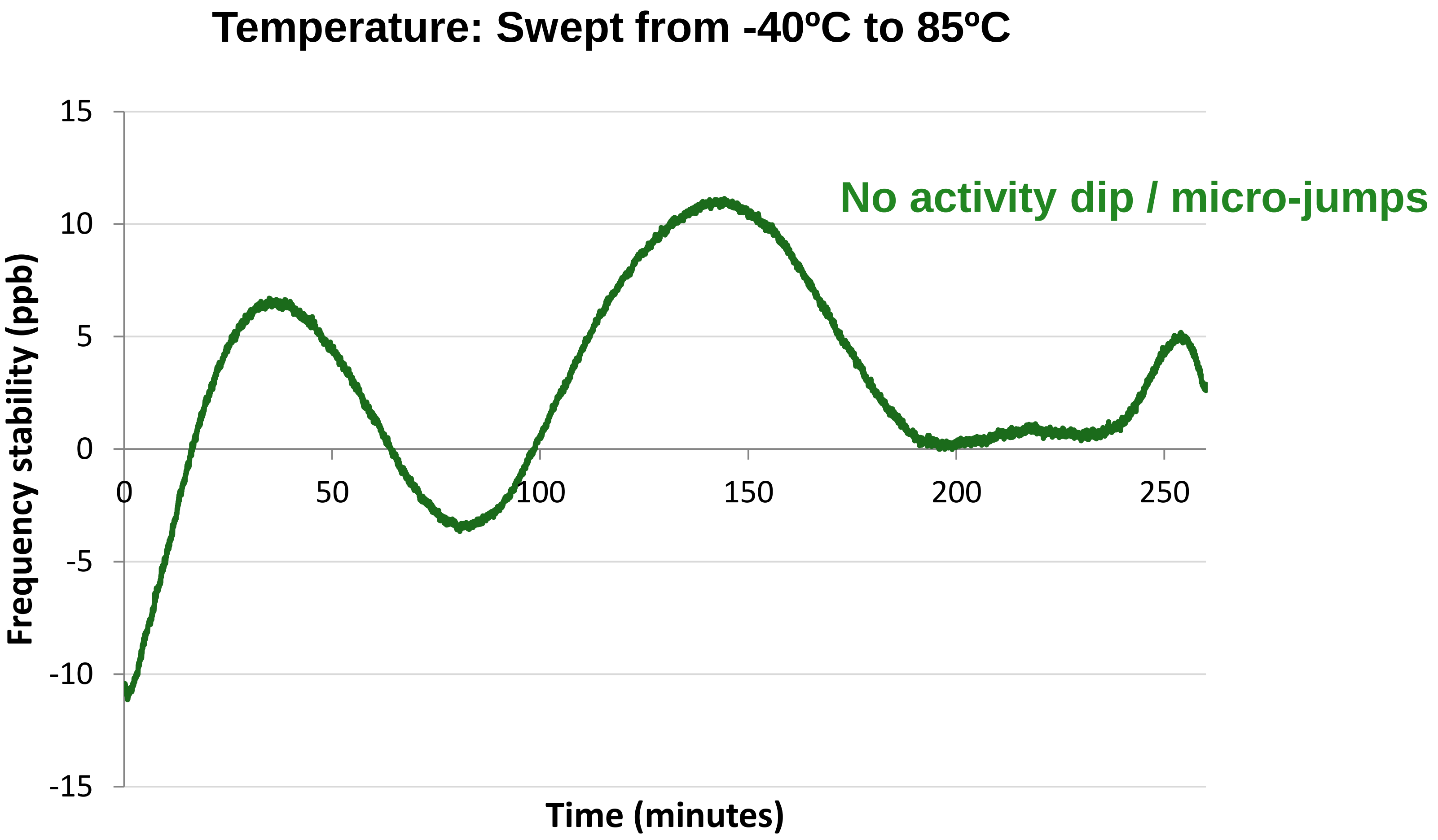
ITU-T G.8262-Compliant MTIE Under Still Air and Airflow Conditions



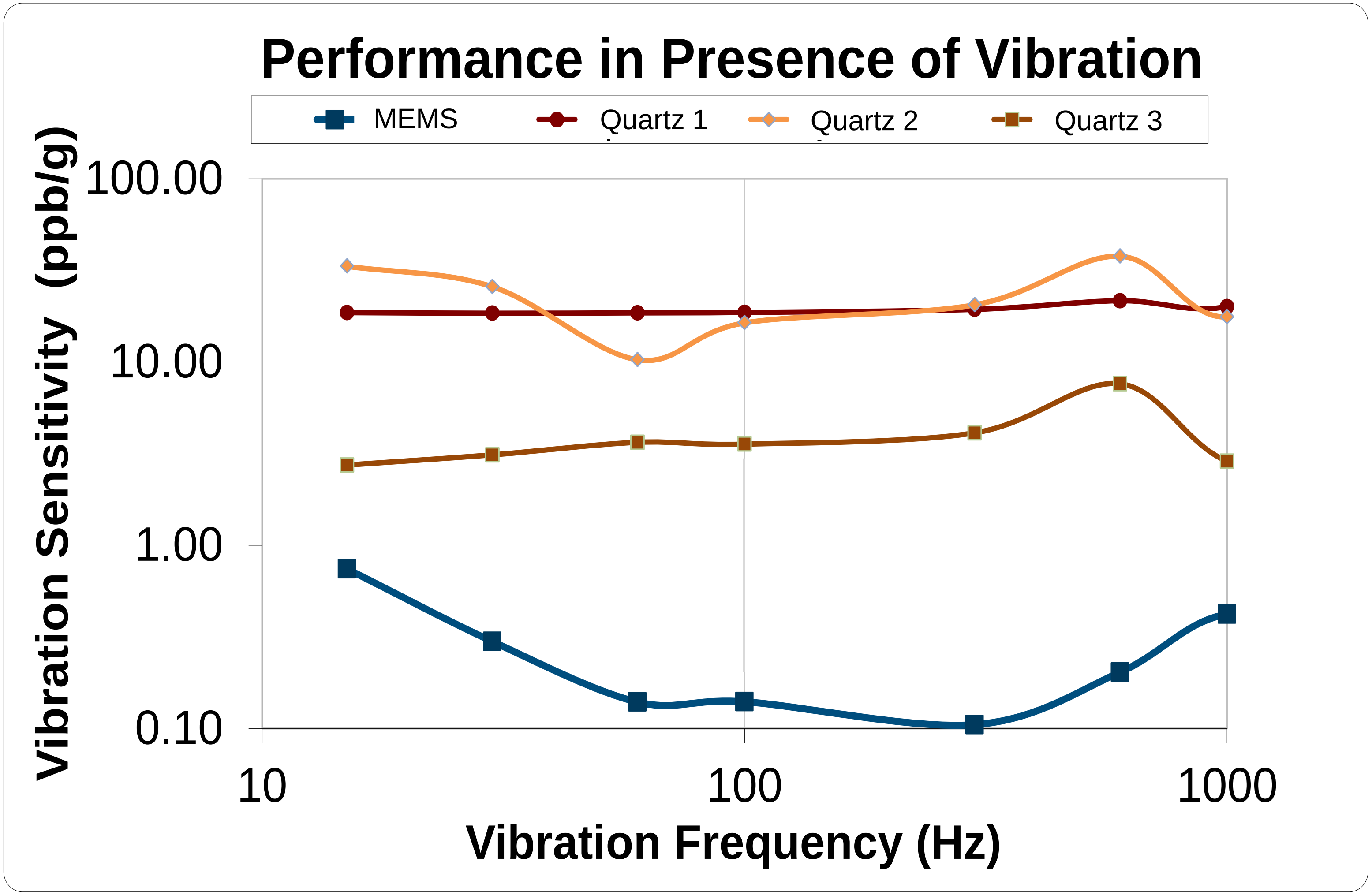
MEMS-Based TCXO: 20 MHz, ±100 ppb, -40ºC to 85ºC

Quartz TCXO, 40 MHz

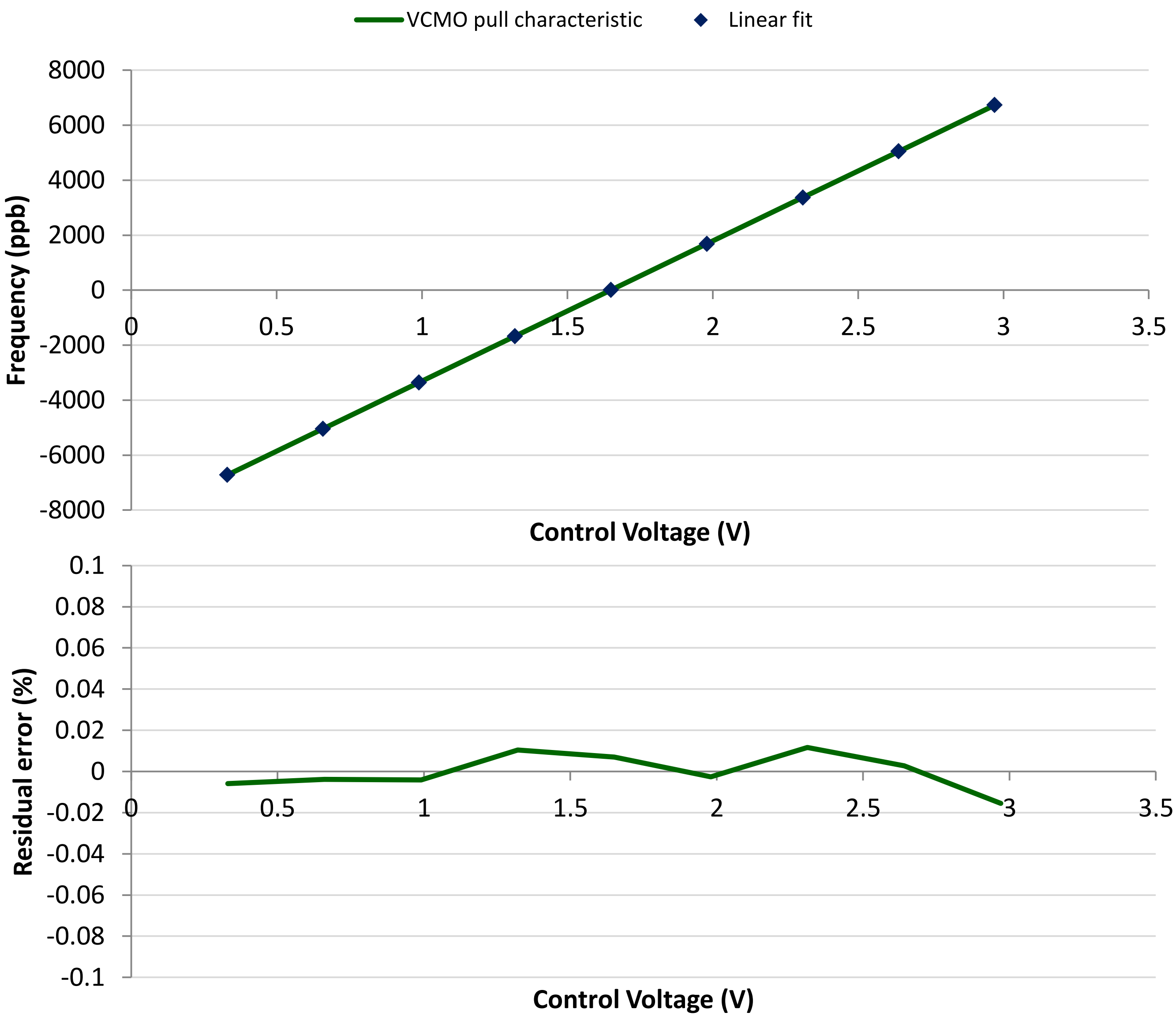
Activity Dips / Micro Jumps



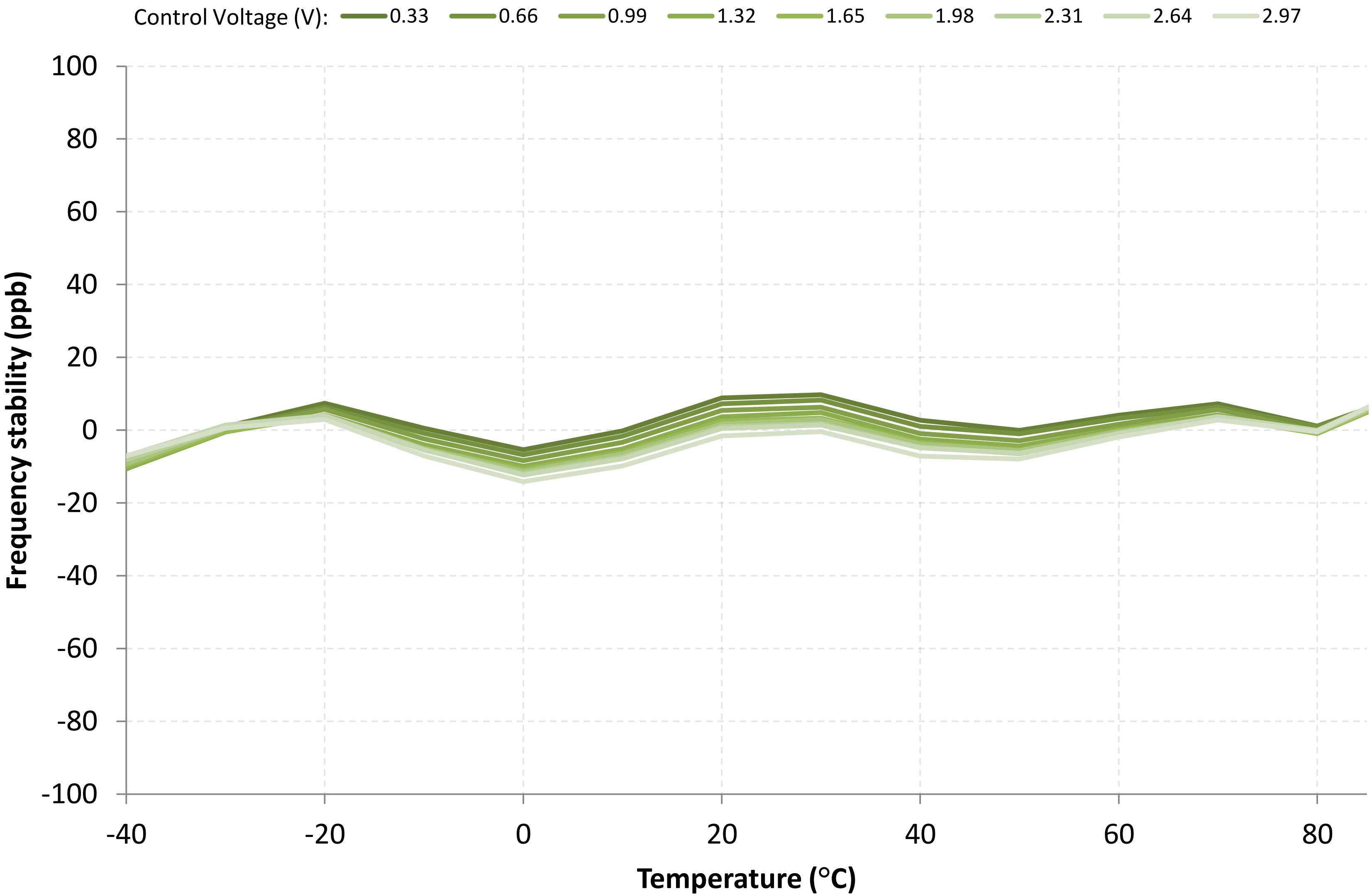
MEMS Resonators Deliver Vibration Immunity



MEMS-Based VC-TCXO Freq-vs-Vctrl Linearity



MEMS-Based VC-TCXO: Vctrl Tuning Skew



Extended Frequency Control Features

Specification	MEMS-Based TCXO	Quartz TCXO
Frequency Range	SE: 1 - 220 MHz DE: 10 - 720 MHz Programmable	SE: 10 - 52 MHz DE: 10 – 200 MHz Fixed frequencies
Outputs	LVPECL / LVDS / HCSL / LVCMOS / Clipped-Sine	LVPECL
Temperature Readout	Yes	No
High Resolution Digital Frequency control (DCXO)	< 0.1ppb resolution at 10kupdate/s	NA

Conclusions

- Novel Dual MEMS resonator + PLL MEMS-based TCXO architecture enables new class of precision oscillators
  - ±100 ppb over -40°C to +110°C

- Enable applications in harsh environmental conditions
  - Wide temperature support up to 105C
  - High temperature ramp rate or airflow
  - Shock and Vibration robustness
  - No activity dips