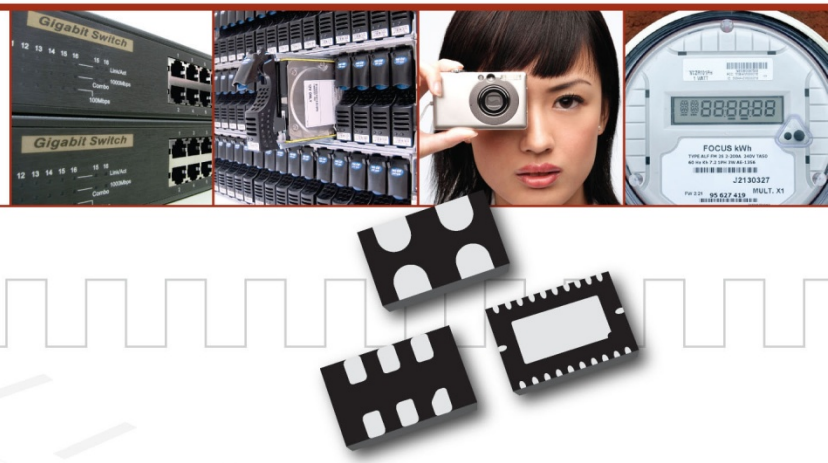
Impact of the local oscillator ΔF/ΔT on the accuracy of IEEE 1588

ITSF 2017



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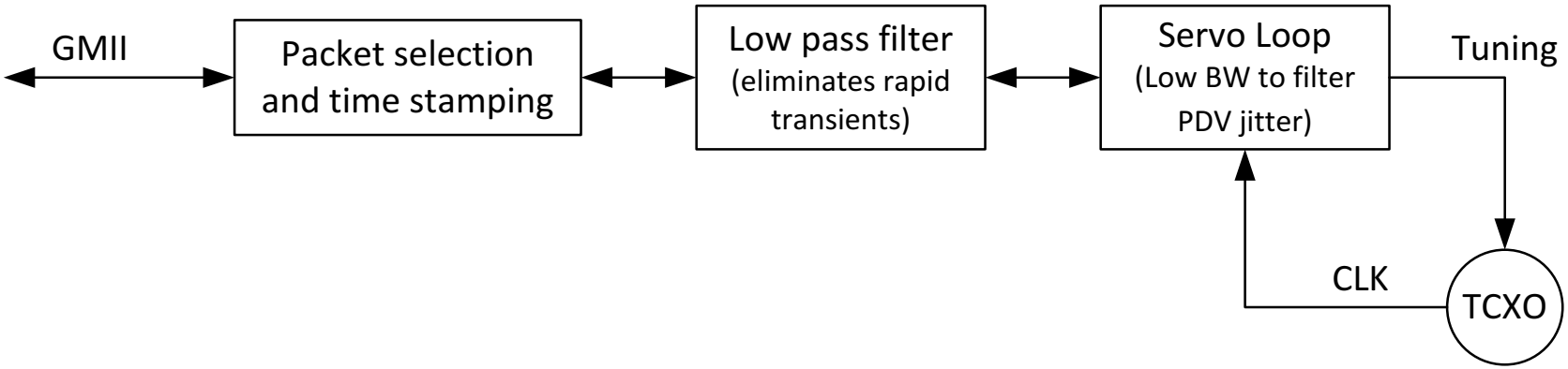
Agenda

- How local oscillator impacts IEEE 1588 performance?
- What advantages are OCXO's offering comparing to Quartz TCXO's?
- How precision MEMS TCXO can offer OCXO-level performance for IEEE 1588 applications?

Local Oscillator Role in IEEE 1588

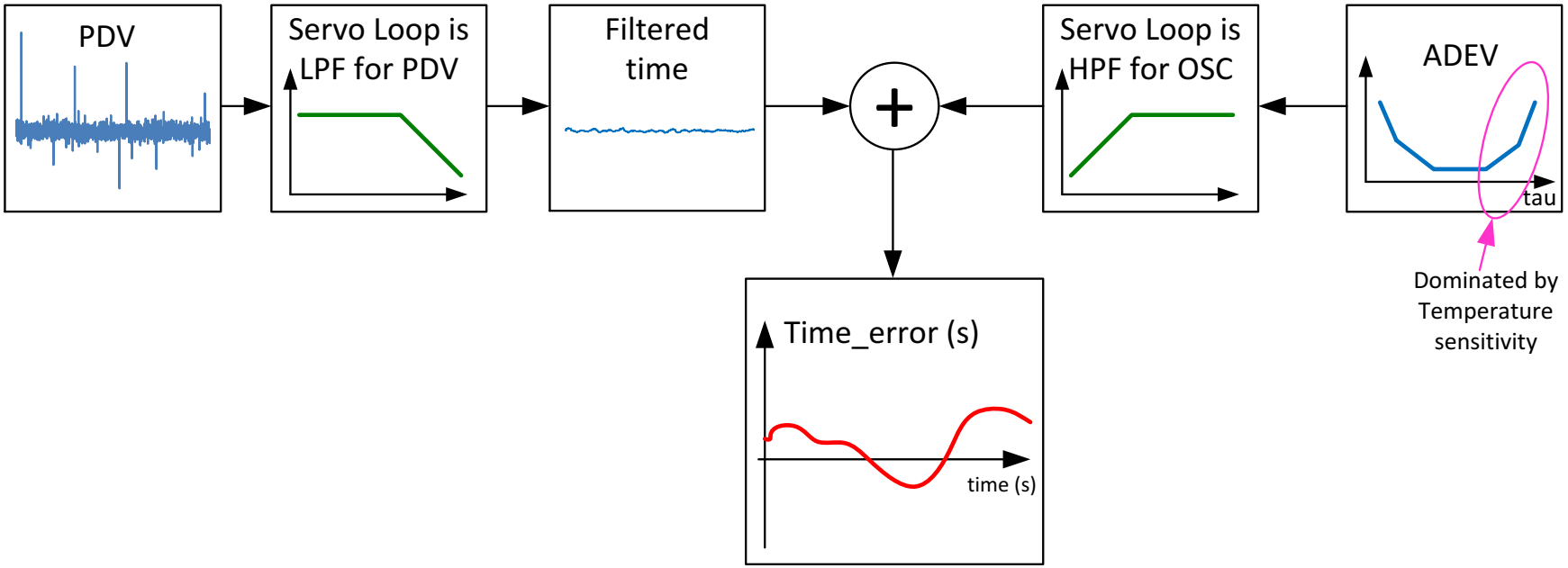
- PDV filtering is one of the key challenges for a PTP system
- For better PDV filtering longer integration time (lower filter bandwidth) is required
- When filtering time constant increases (better PDV filtering) PTP servo relies on a good wander performance of the local oscillator



Oscillator characteristics determine the limits of PDV filtering capability

Note: servo loop algorithm may use higher bandwidth in unlocked state to ensure fast lock time and reduce the bandwidth once locked to improve filtering performance

Servo Loop BW is a Tradeoff between PDV filtering and Oscillator Noise

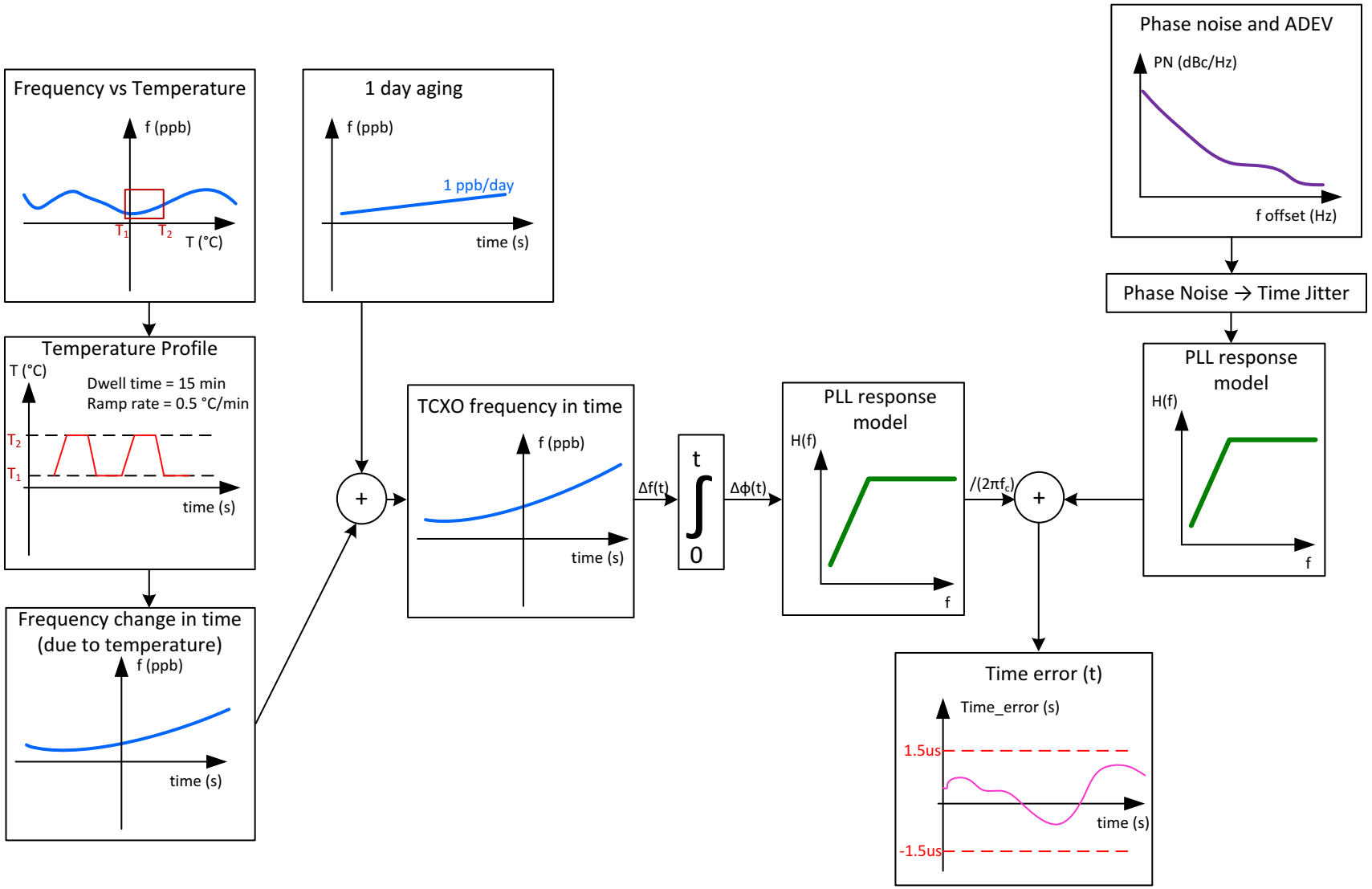


- Time Error is a combination of Network Performance and Oscillator Noise
- Tradeoff between PDV filtering and Oscillator Noise is defined by Servo Loop Bandwidth

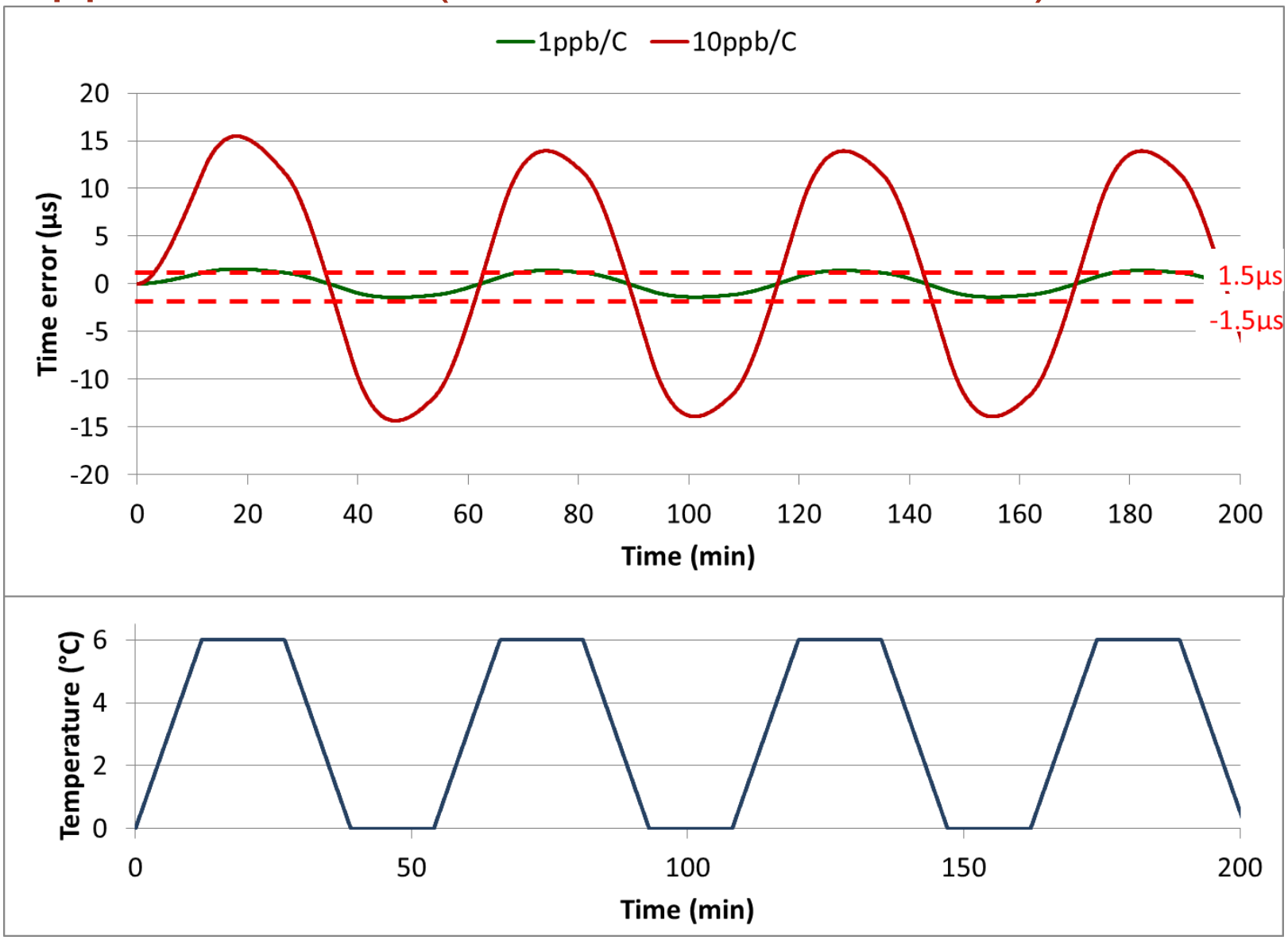
Properties of the Oscillator that affect PTP Performance

- **Sensitivity to temperature changes (defined as Frequency Slope or ΔF/ΔT)**
  - Dominating contributor to Time Error
  - Ambient temperature variations translate to frequency change of the oscillator
- **Short term aging (1-day aging)**
  - Has little impact on PTP performance if 1 ppb/day or better
- **Native oscillator wander**
  - In good quality TCXO's is small enough and doesn't impact µs-level Time Error performance
  - Important for achieving <100 ns Timer Error performance level

Simulation methodology of Local Oscillator impact on PTP performance



PTP Performance with 1 ppb/°C and 10 ppb/°C TCXO (Time Constant 10 min)



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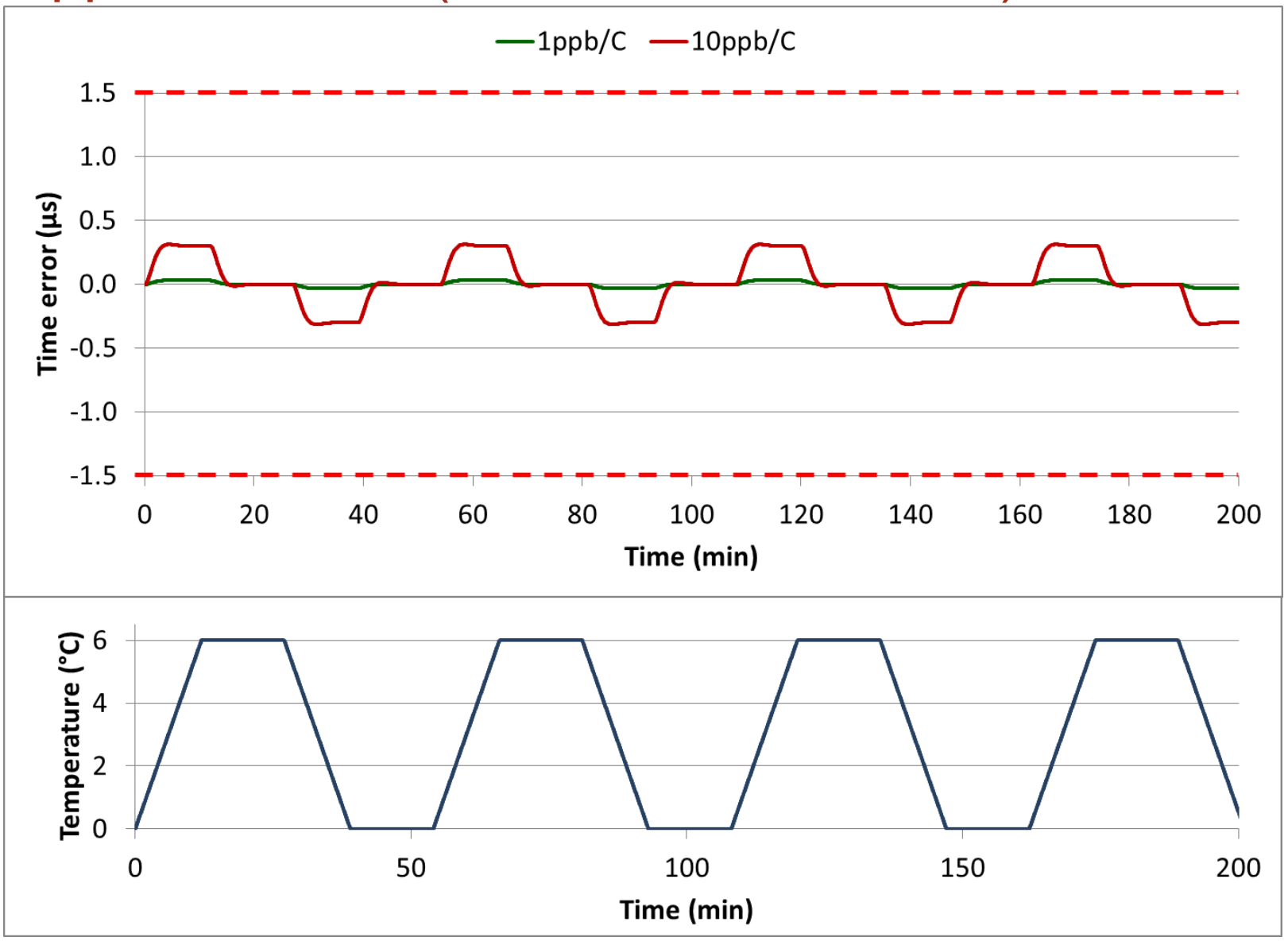
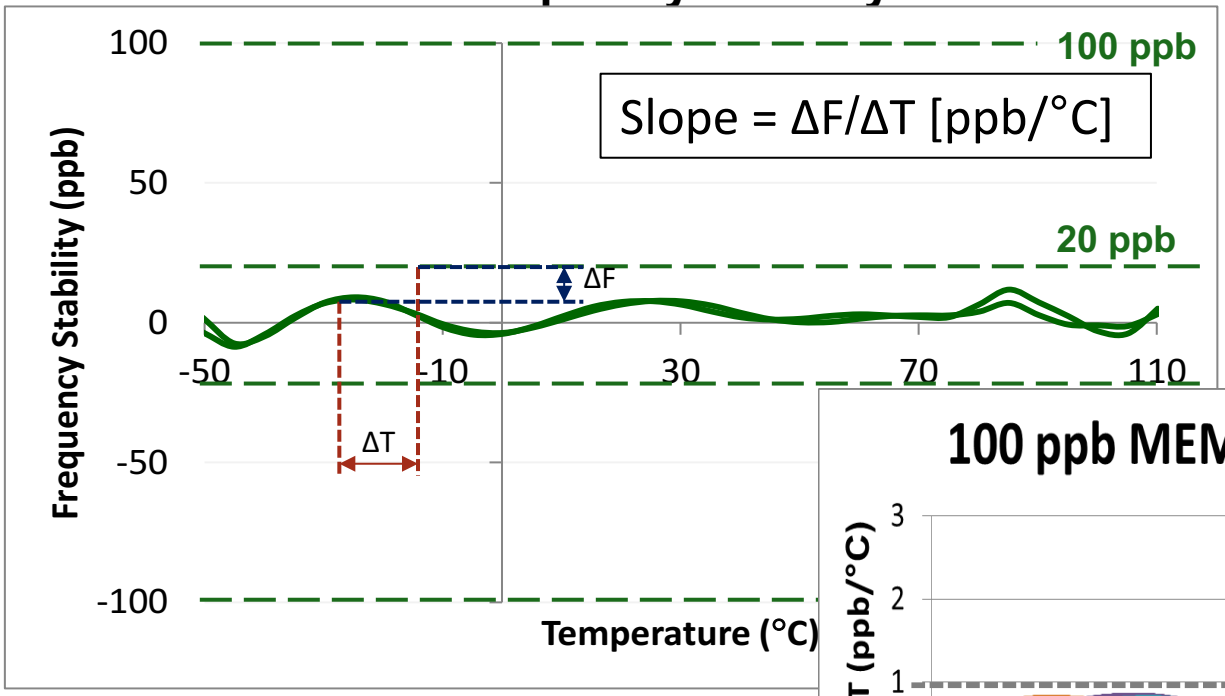


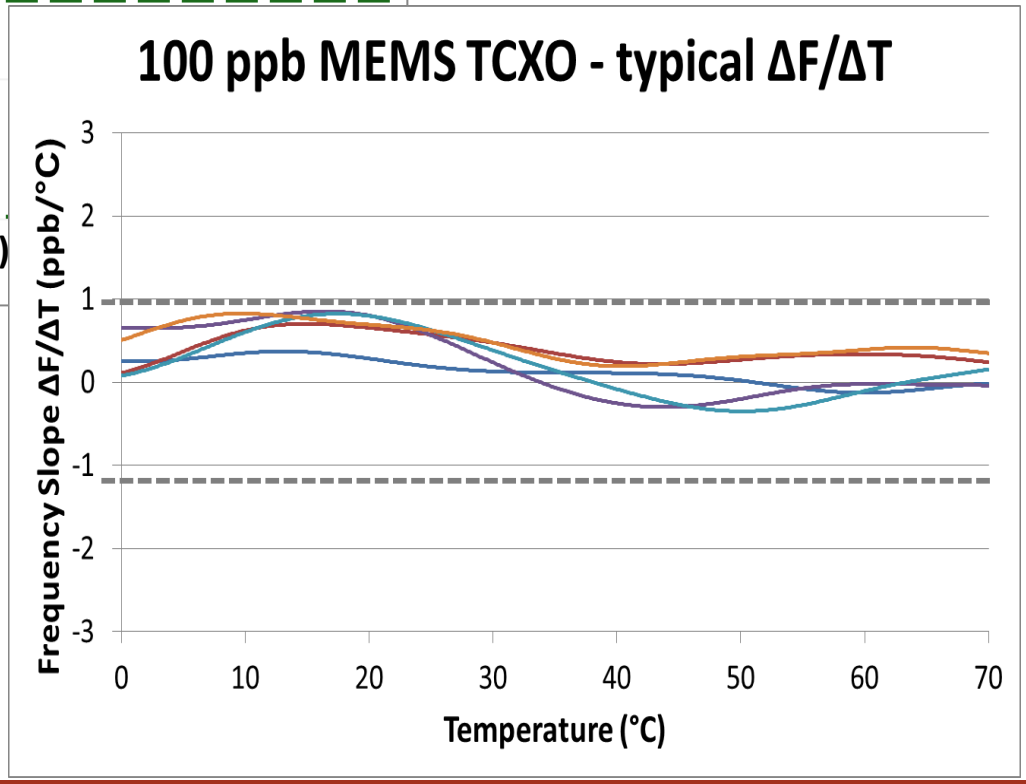
How do OCXO's compare to MEMS TCXO?

OCXO	MEMS TCXO
• **Frequency slope (ΔF/ΔT)** 1 ppb/°C or better	• **Frequency slope (ΔF/ΔT)** 1 ppb/°C or better
• **Low sensitivity to airflow and temperature transients**	• **Low sensitivity to airflow and temperature transients**
• **Frequency Stability** 20 ppb or better	• **Frequency Stability** 50 ppb
• **Large package > 9x7 mm**	• **Small size 5 x 3.2 mm**
• **High power > 500 mW**	• **Low power <150 mW**

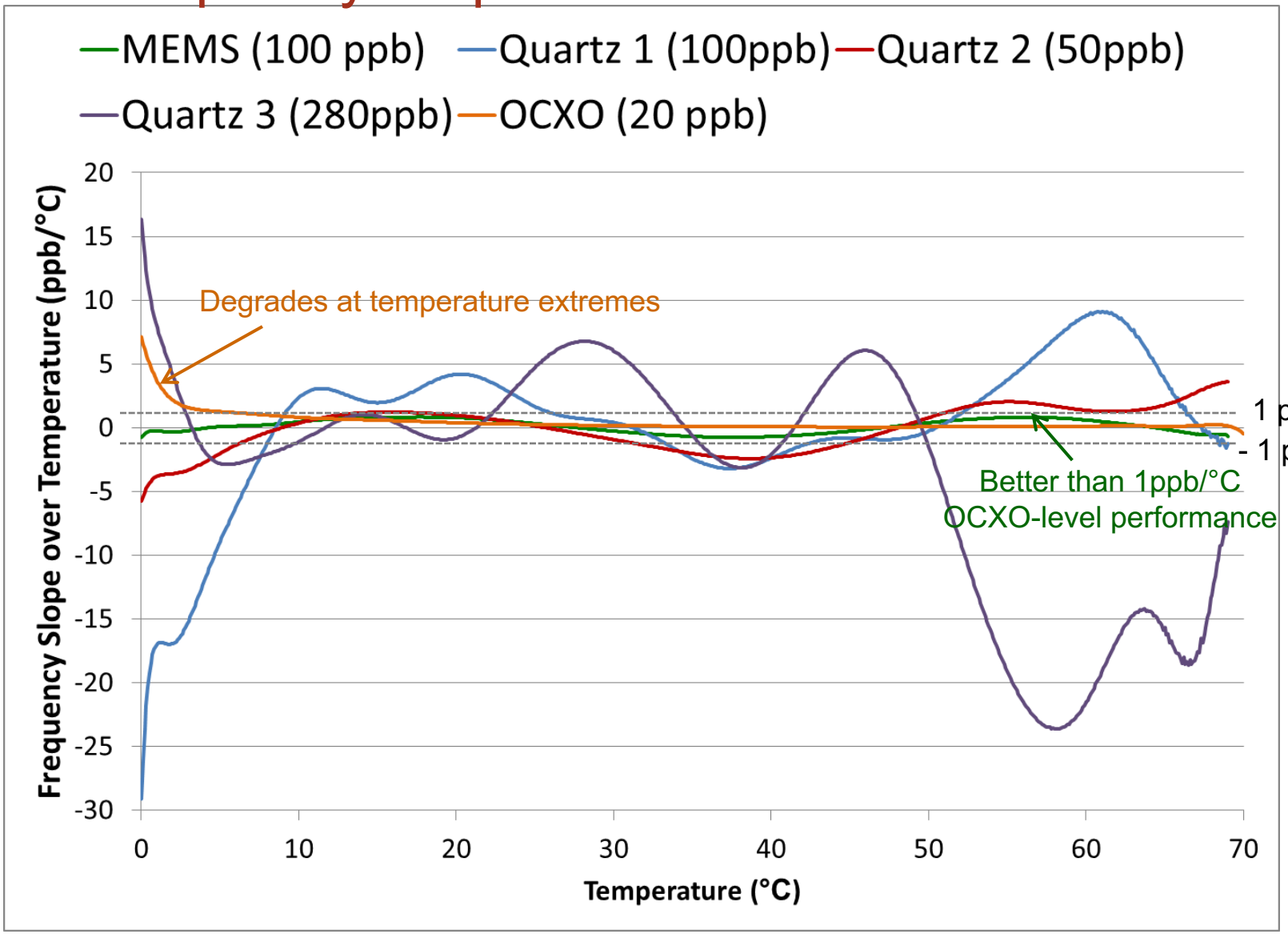
Frequency Slope over Temperature

MEMS-Based TCXO Frequency Stability – Measured Results

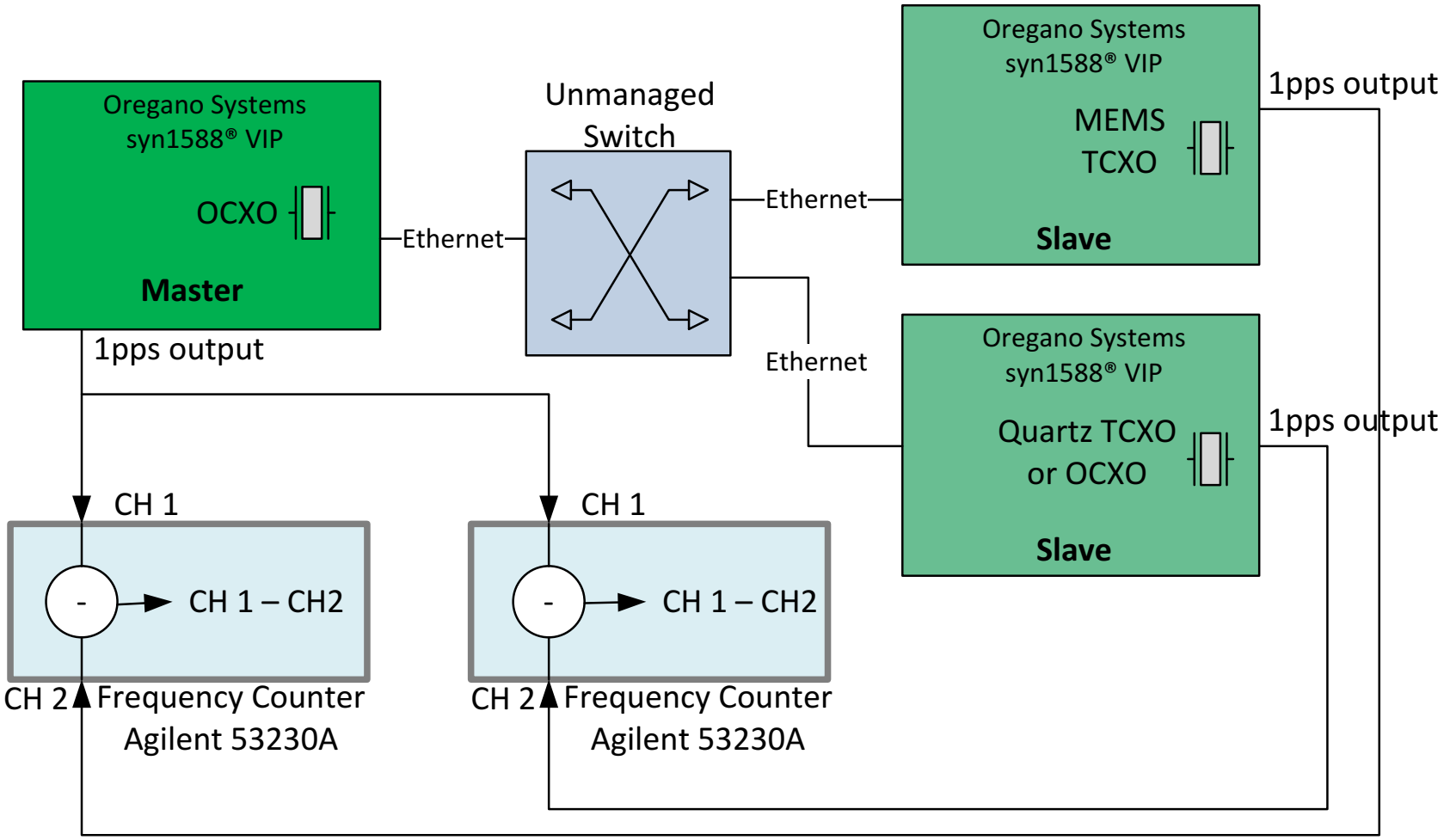




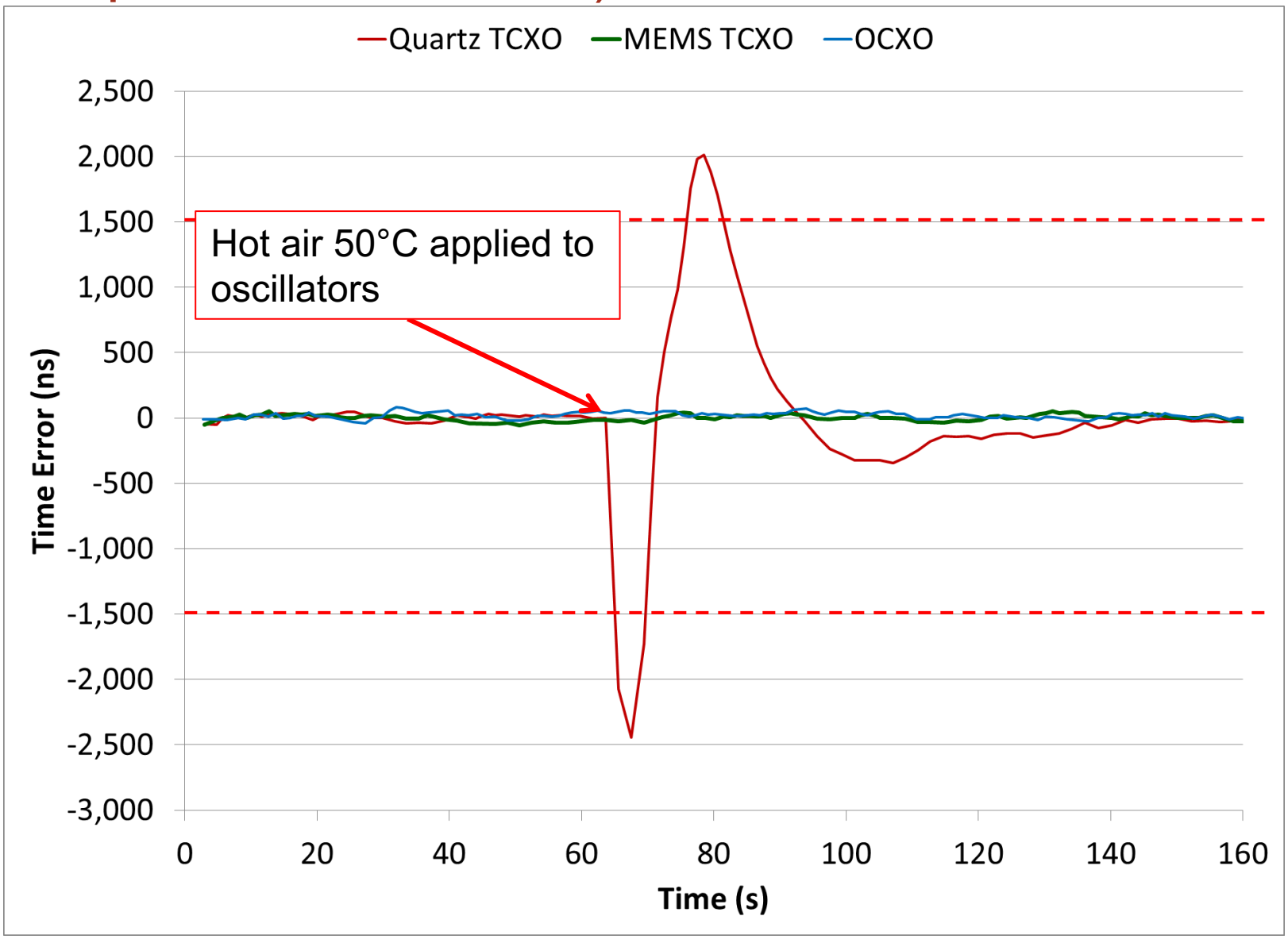
MEMS Precision TCXO delivers OCXO-level Frequency Slope Performance



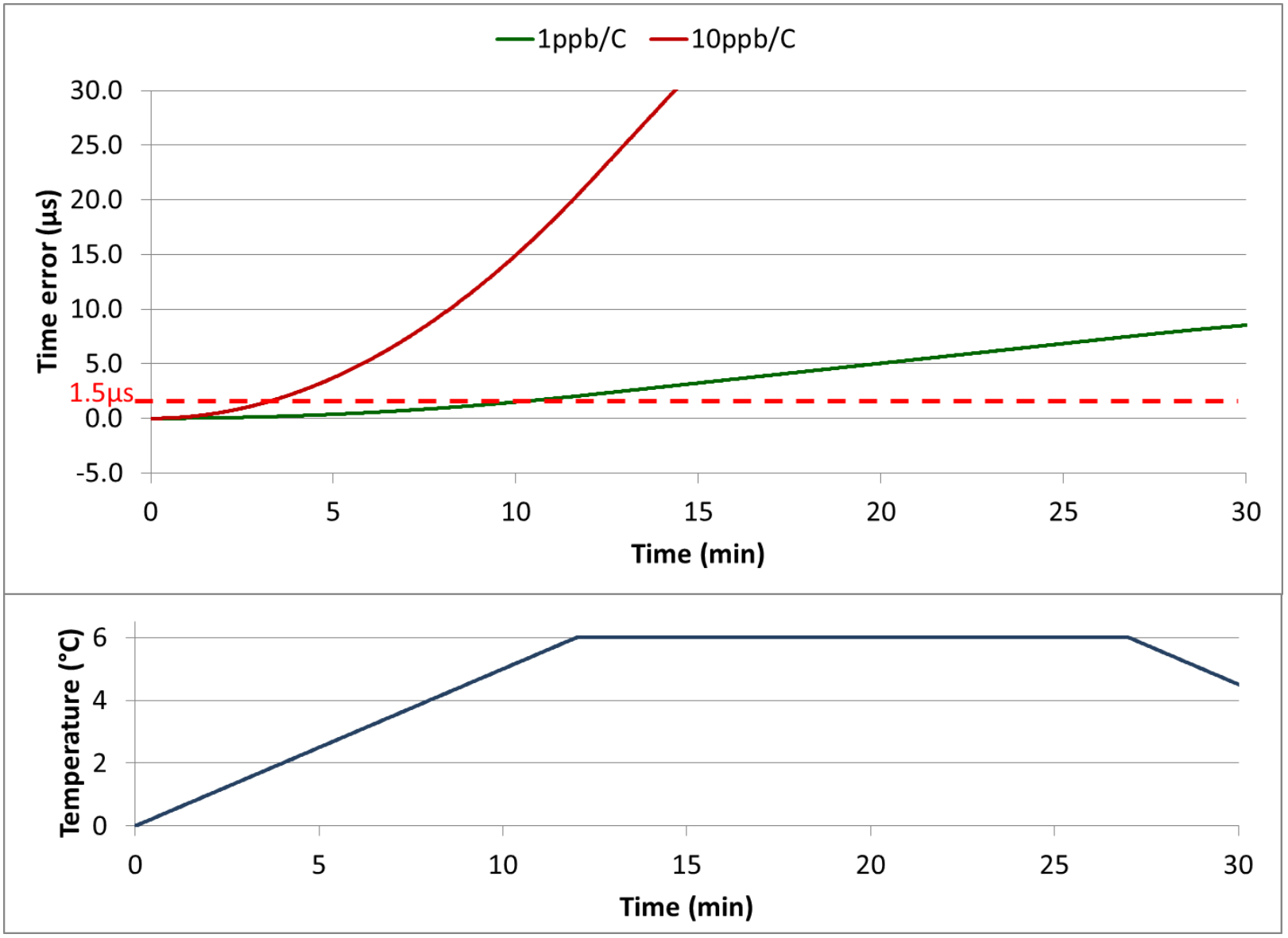
Time Error Measurement Setup



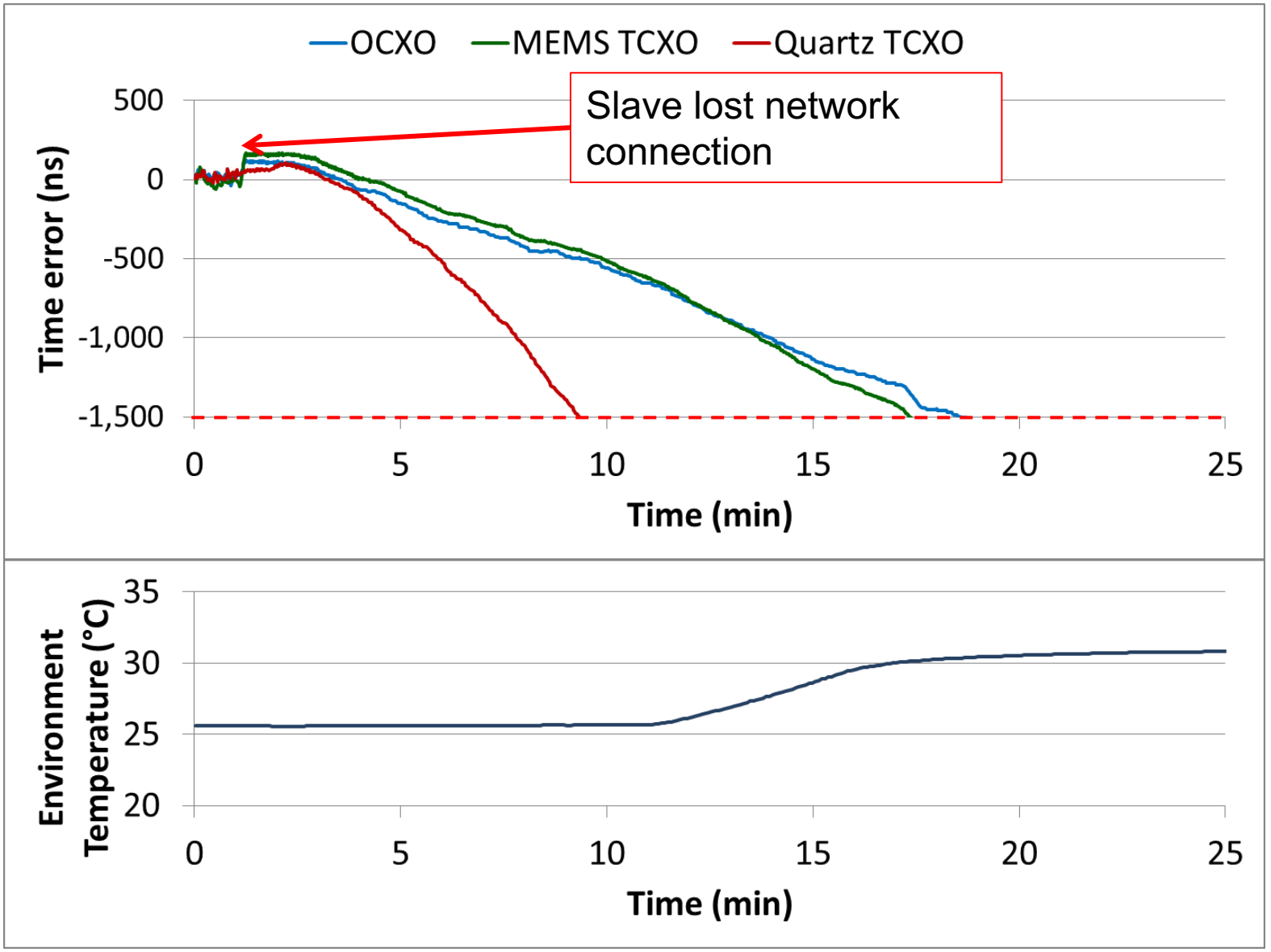
Time Error Measurement Data (Temperature Transient)



Short term Holdover Simulation



Short term Holdover Measurement



Conclusions

- **Frequency Slope impacts PTP performance not Frequency Stability** over full operating temperature range

- Frequency stability of TCXO is not a good measure of frequency slope

- **MEMS-based precision TCXO's** have been designed to
  - minimize Frequency Slope over Temperature (5x to 20x improvement comparing to Quartz TCXO's)
  - minimize sensitivity to environmental factors, like airflow and temperature transients

- MEMS-based TCXO's and **can be used to replace OCXO's in PTP applications**

Thank You!

Questions?