Delivering OCXO-grade PTP Performance with MEMS Precision TCXO

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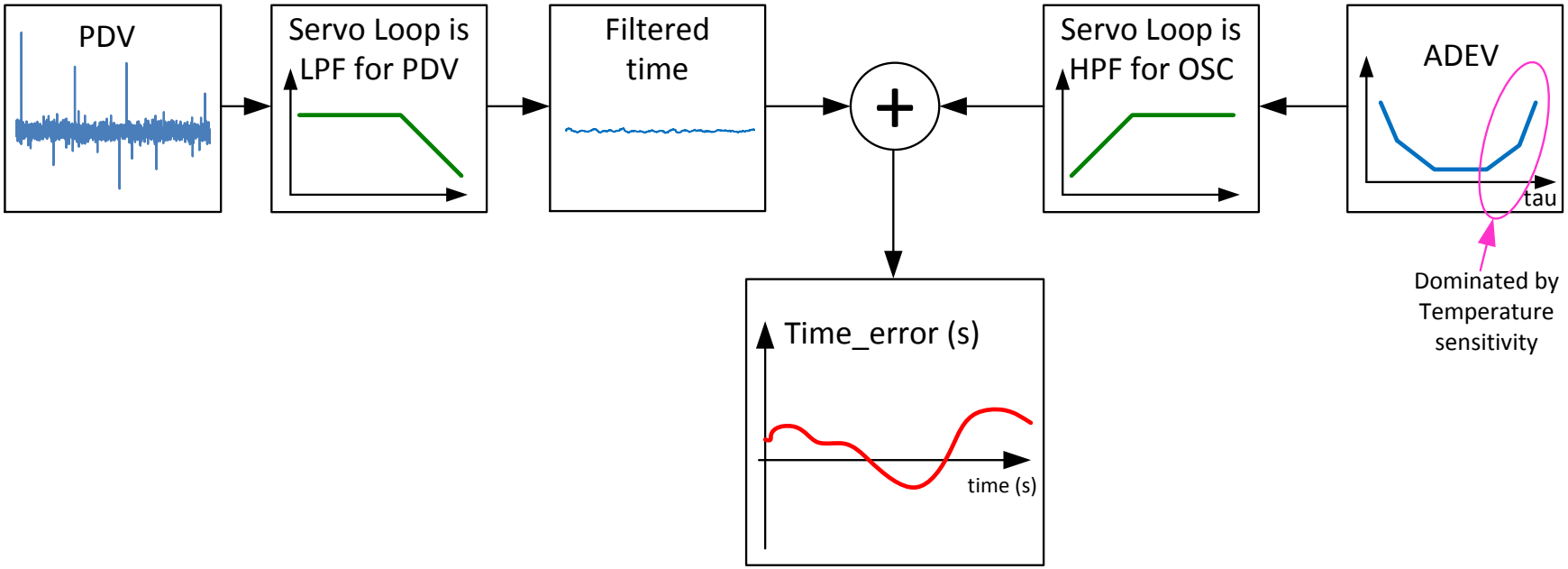
Introduction

- Ethernet is becoming increasingly popular method for transferring data in a mobile backhaul, but it's asynchronous in nature
- LTE BS (eNodeB) requires 1.5 us time/phase synchronization
- PTP can be used to achieve sub-microsecond time synchronization over a packet network, like Ethernet
- High quality local oscillator is required for best PTP performance
- OCXO's are considered higher performance than TCXO's because they are less sensitive to airflow and offer tighter frequency stability
- **Do you need a frequency stability of OCXO if you can get the same level of ΔF/ΔT performance with precision MEMS TCXO?**

Factors affecting PTP Accuracy

- **Local oscillator quality**
  - Sensitivity to external conditions (for example, slope of frequency over temperature, sensitivity to VDD change)
  - Wander
- **Control loop design**
  - Control loop bandwidth/transfer function
- **Packet delay variation**
  - Network load
  - Network architecture
  - Use of network devices with PTP support (Transparent Clocks, Boundary Clocks)
- **Time stamping accuracy**
  - Typically hardware based time stamping used to avoid software delays
  - Hardware timestamping resolution is usually in nanosecond range

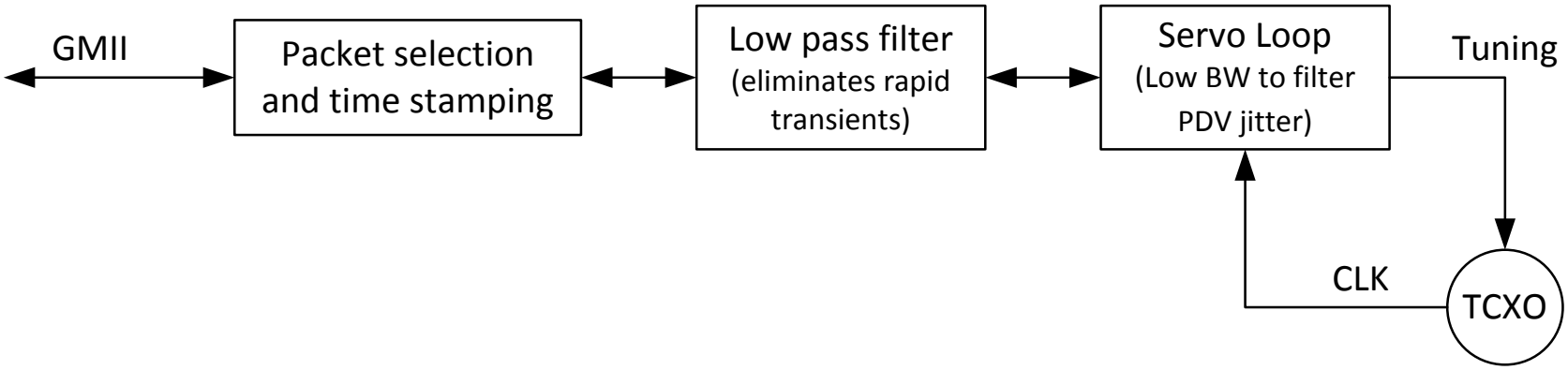
Servo Loop BW is a Tradeoff between PDV filtering and Oscillator Noise



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

Oscillator performance determines the limits of PDV filtering capability

- Lower servo loop bandwidth → better PDV filtering
- Requires oscillator with good ADEV at long tau (dominated by temperature effects)
- ΔF/ΔT of an oscillator (slope) is a Temperature to ADEV conversion factor
- **For best PTP performance ΔF/ΔT of an oscillator should be minimized**



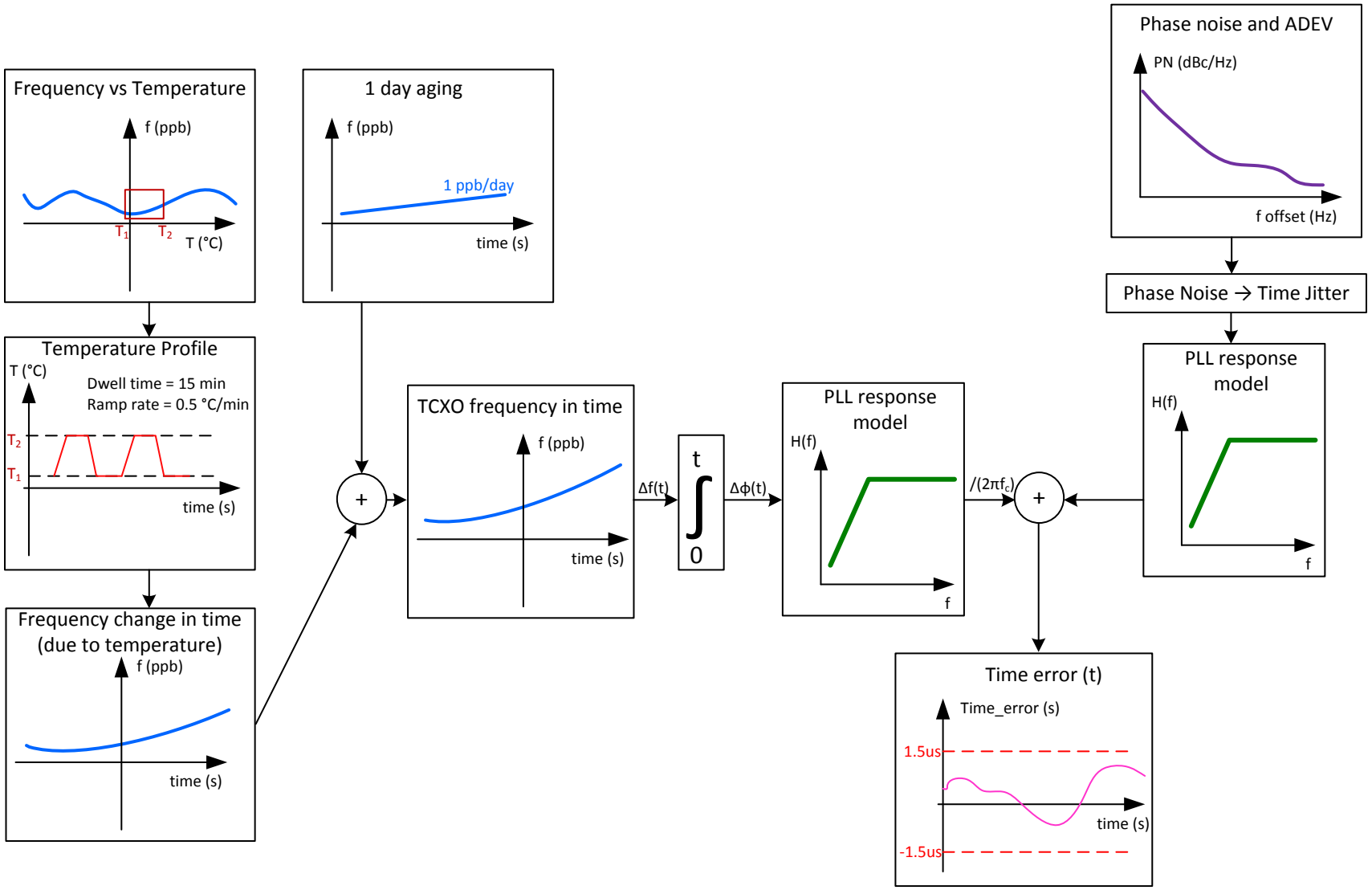
Oscillator characteristics determine the limits of PDV filtering capability

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

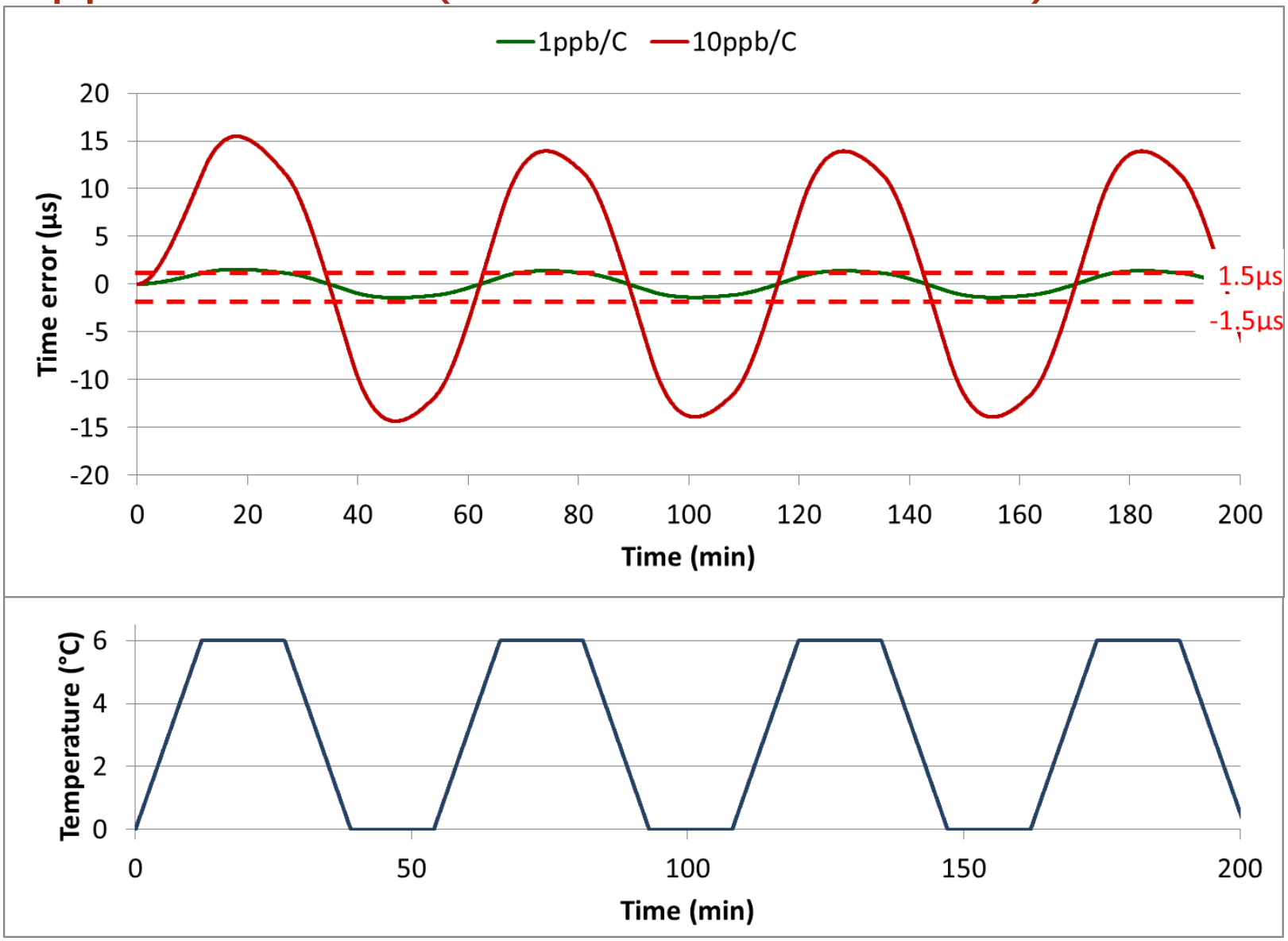
Properties of the Oscillator that affect PTP Performance

- **Sensitivity to temperature changes (defined as Frequency Slope)**
  - Dominating contributor to Time Error
  - Ambient temperature variations translate to oscillator output frequency change
- **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

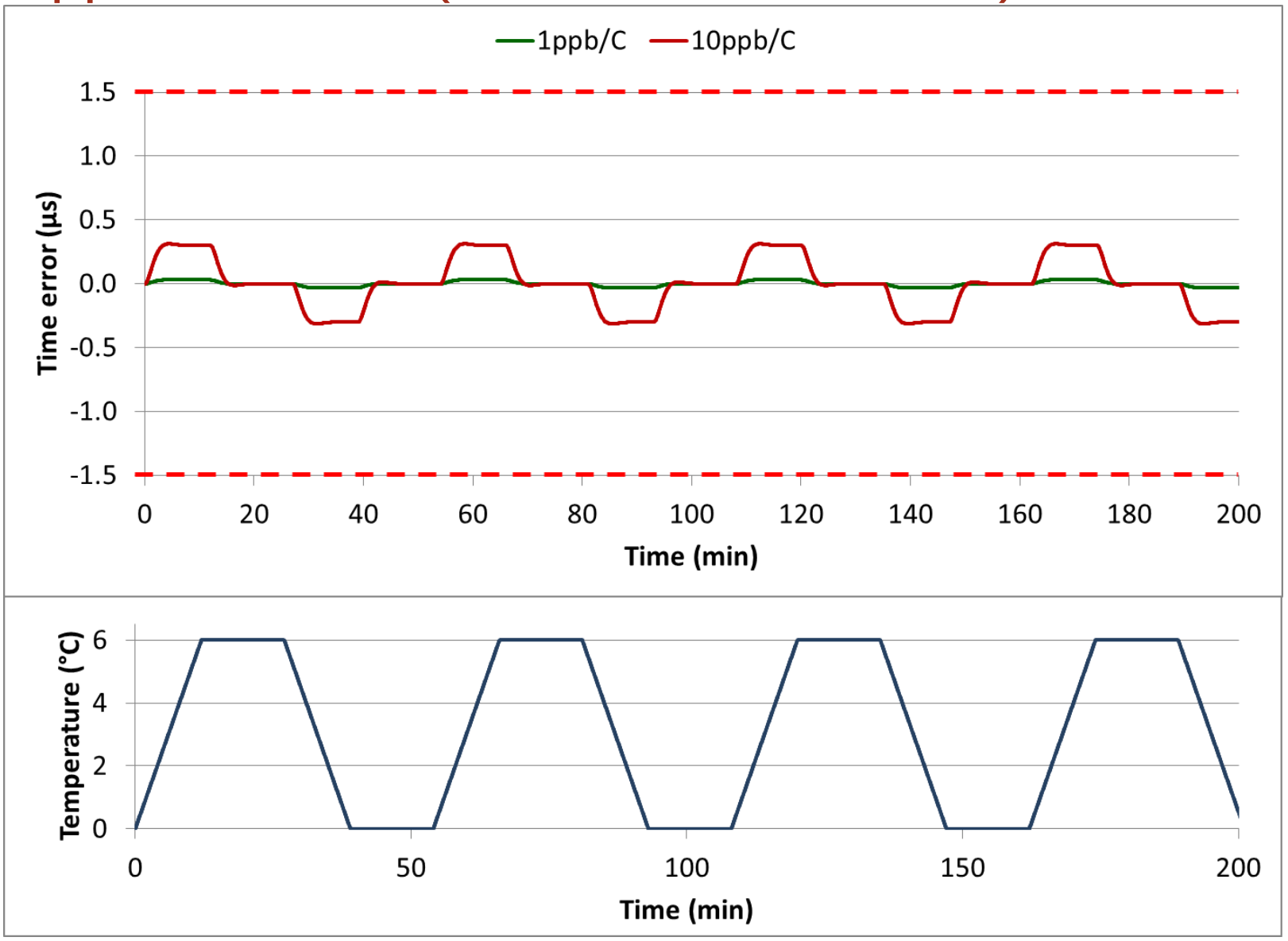
Simulation methodology of Local Oscillator impact on PTP performance



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

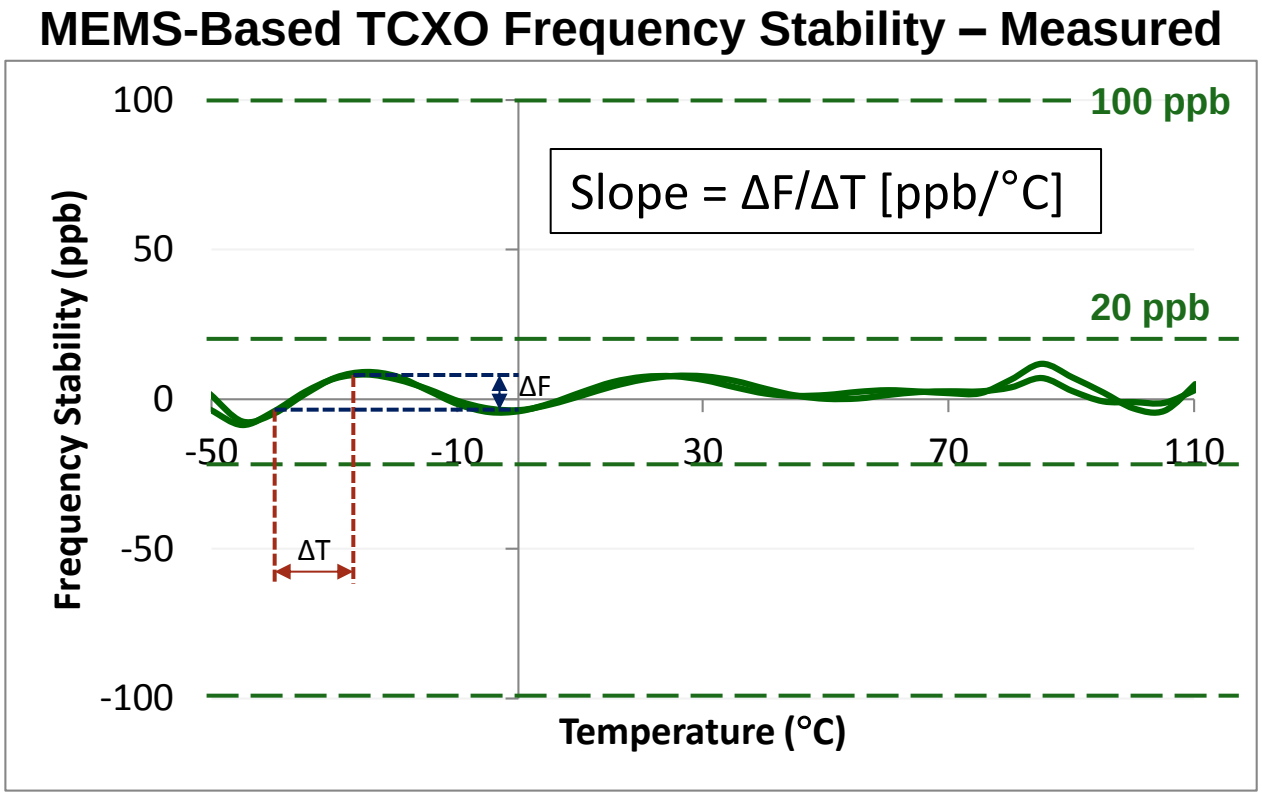


PTP Performance with 1 ppb/°C and 10 ppb/°C TCXO (Time Constant 1 min)

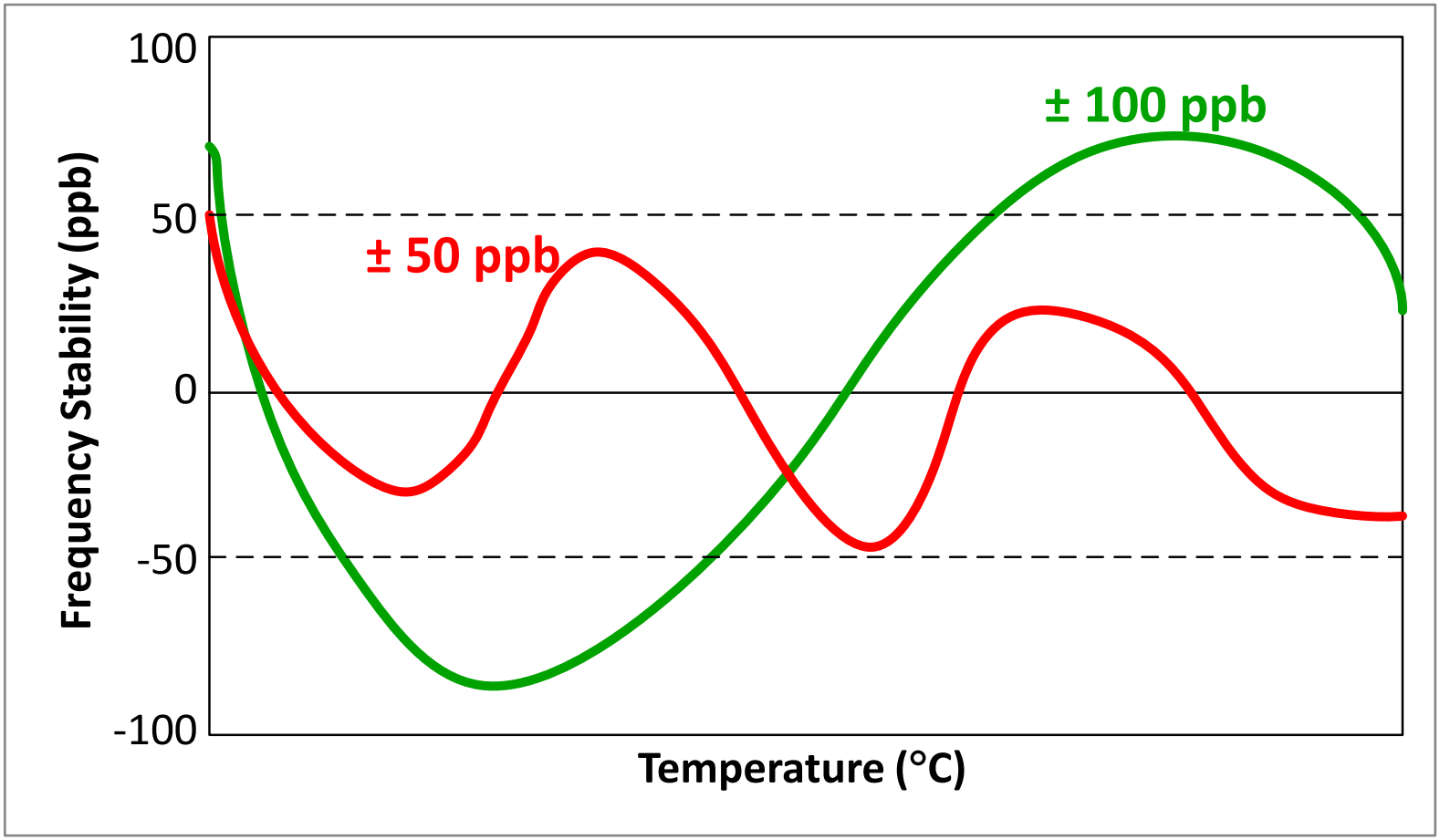


Frequency Slope over Temperature

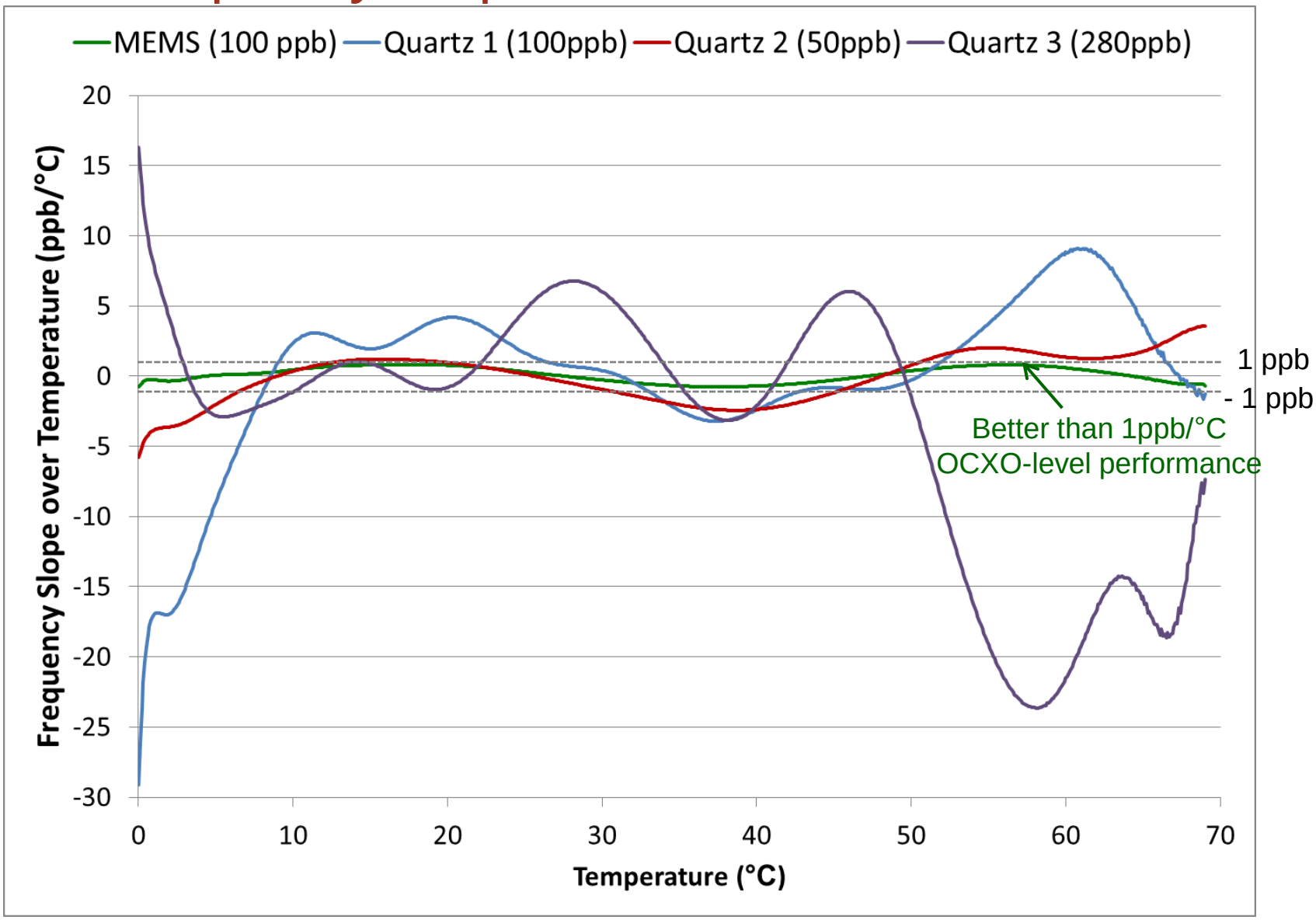
- Frequency Slope over Temperature is a measure of frequency change due to temperature change by 1°C and is typically expressed in ppb/°C



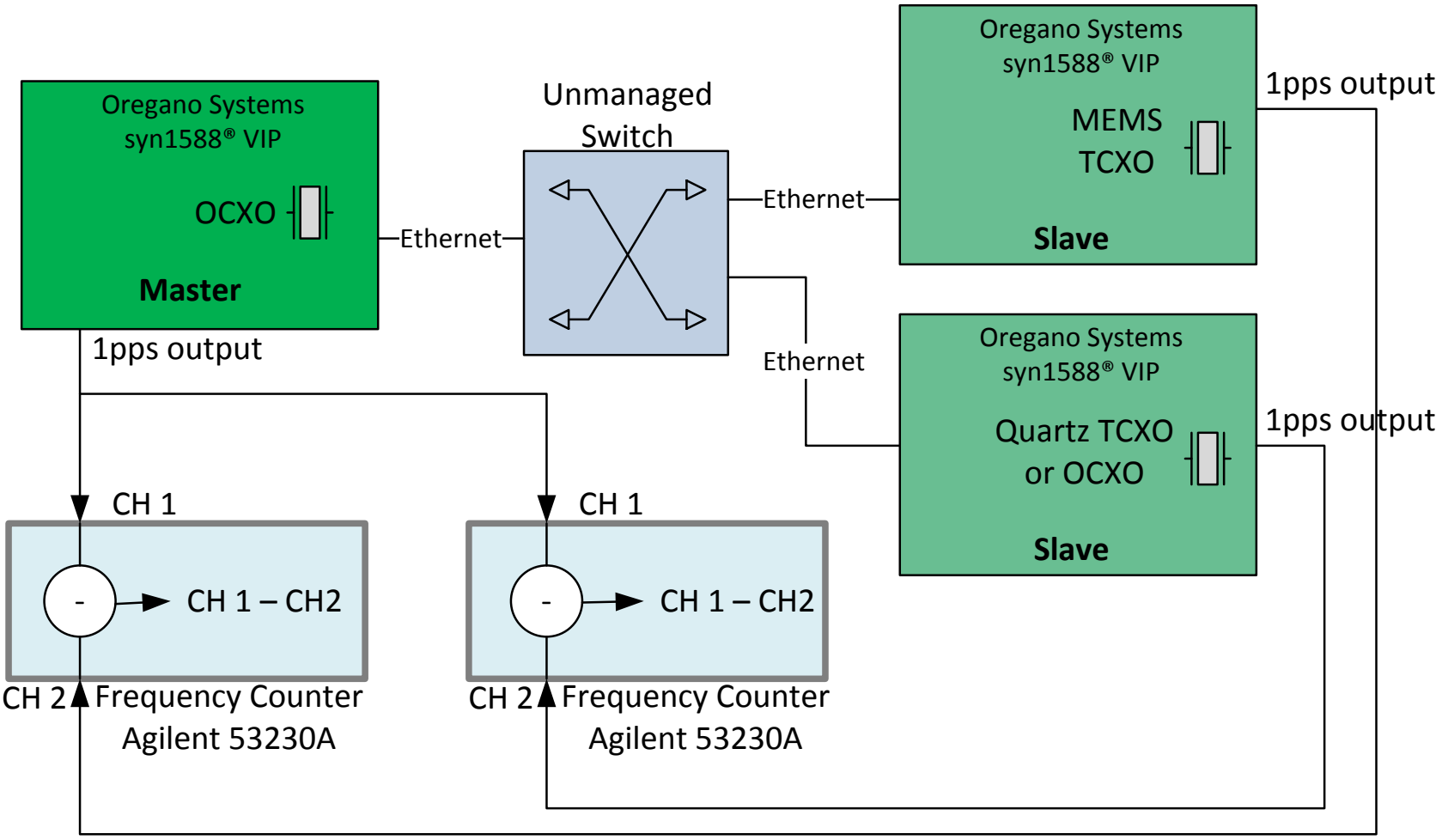
Which part is better? 50 ppb or 100 ppb?



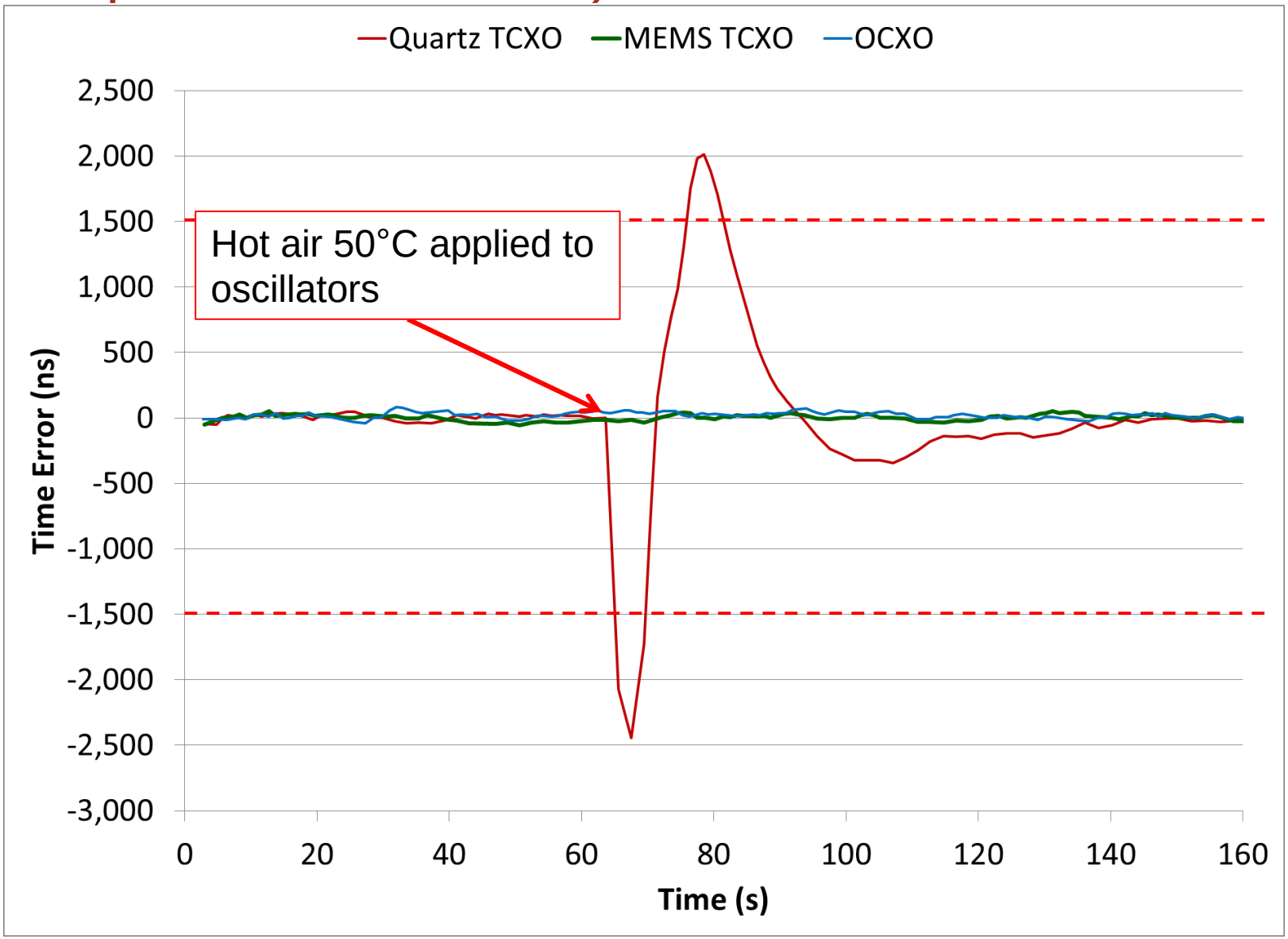
MEMS Precision TCXO delivers OCXO-level Frequency Slope Performance



Time Error Measurement Setup



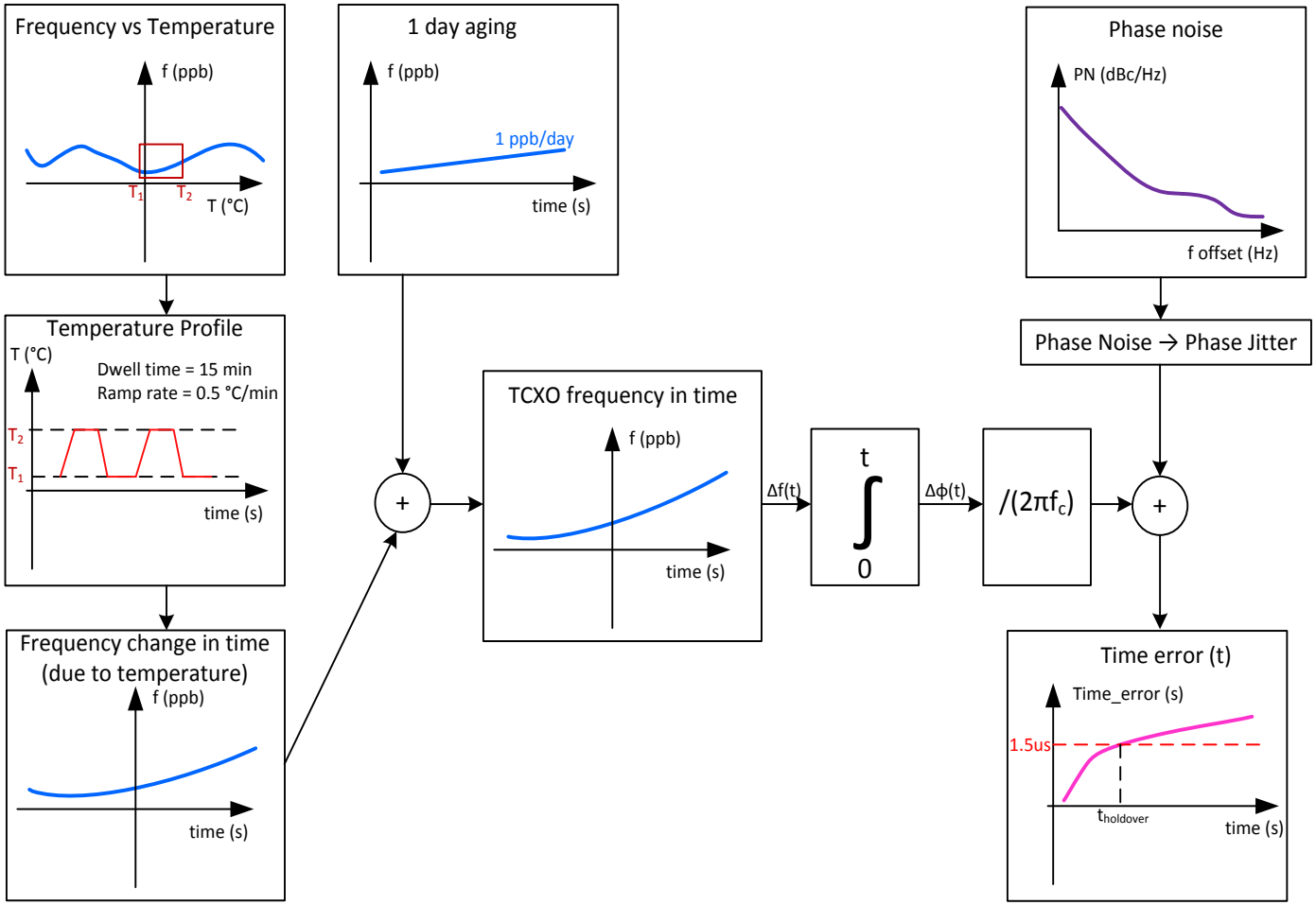
Time Error Measurement Data (Temperature Transient)



Short Term Holdover is a Reflection of the Oscillator Performance

- Short term holdover may range from few seconds to few hours
- During holdover servo loop freezes the TCXO tuning at the last known good value
- Holdover performance is a reflection of the oscillator characteristics
- Possible causes may include
  - Master change – few seconds to few minutes
  - Equipment failure or reconfiguration – up to few hours
- During the holdover clock should maintain Time Error within the specified limits while running of the local oscillator

Short term Holdover Simulation



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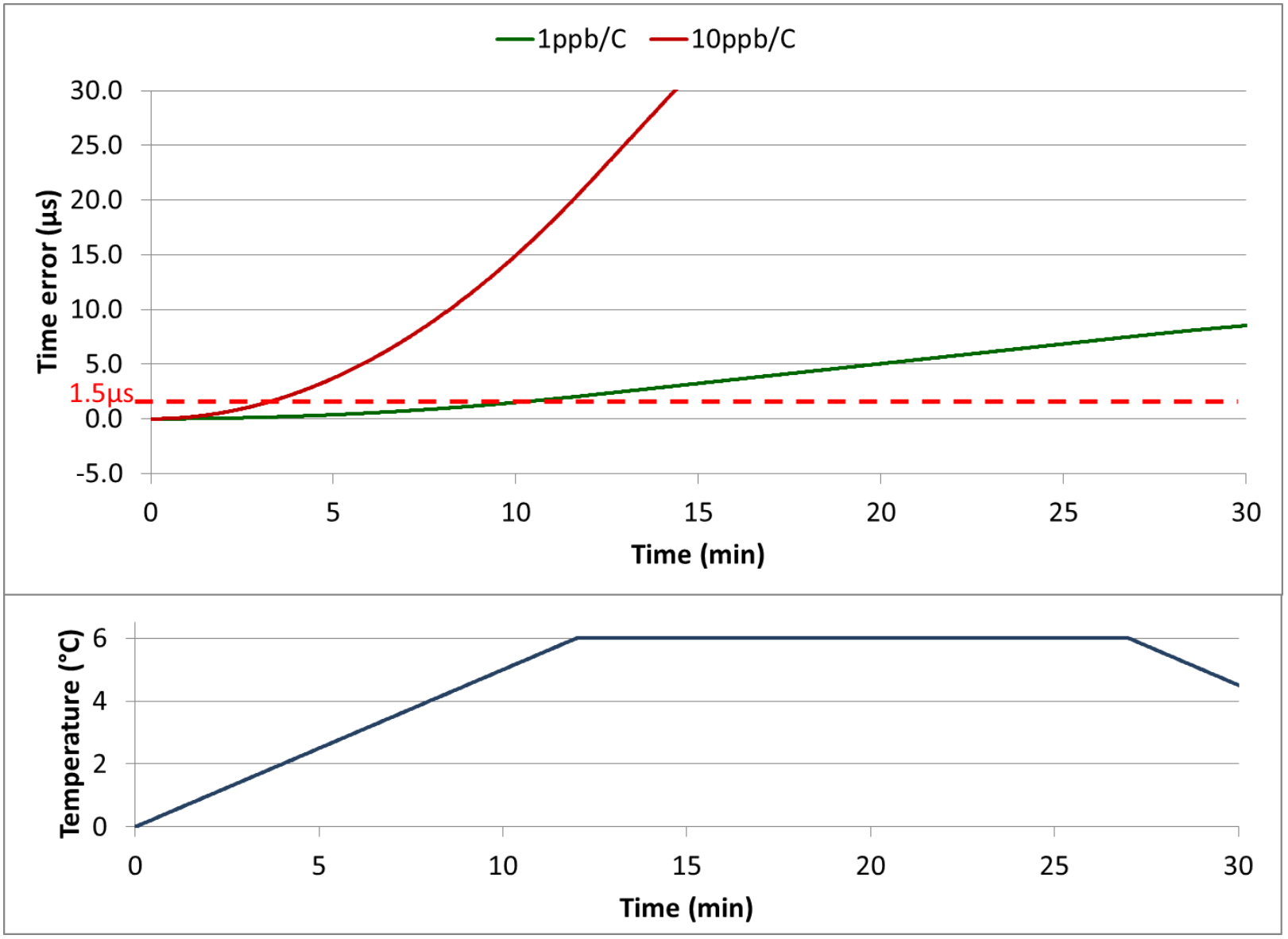
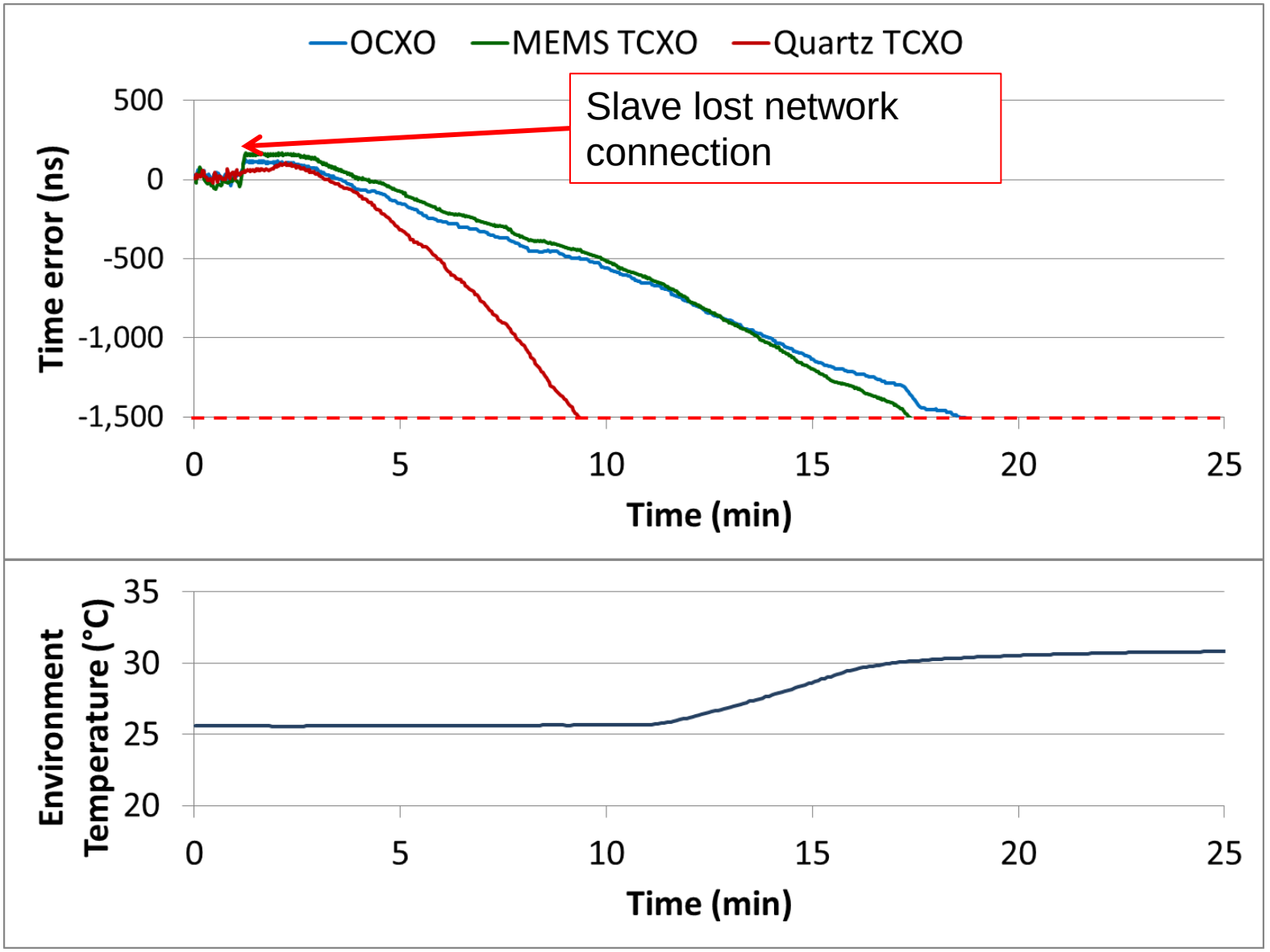


Short term Holdover Measurement



Conclusions

- PTP devices require **high quality oscillators** to achieve good accuracy
- Better stability oscillators allow tuning servo loops for **better PDV filtering**
- **Frequency Slope impacts PTP performance not Frequency Stability** over full operating temperature range
- TCXO's with the same Frequency stability spec may have significantly different Slope over Temperature
- **MEMS-based precision TCXO's** have been designed to minimize Frequency Slope over Temperature (5x to 20x improvement comparing to Quartz TCXO's) and **can be used to replace OCXO's in PTP applications**
- SFP modules is an example of an application where MEMS-based precision TCXO's provide **OCXO-level performance** while saving critical space and power

Thank You!

Questions?