System level synchronisation reference compensation for extending time holdover

Frederic VITTRANT

Ullas Kumar

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Topics

- Holdover and expectations
- Holdover as a system feature
- Oscillator based holdover
- System level challenges
- Deployment models & results

Drive for holdover

1 Demanding applications

- 5G performance
  – carrier aggregation
- URLLC
  – reliability & availability

2 GNSS vulnerability

- Jamming
- Spoofing
- Weather & other environmental
- Deployment inaccuracies

3 New network architectures

- Distributed & open architectures
- Generic equipment designs
- Superset of configurations

4 Challenging deployments

- Distributed & open architectures
- Generic equipment designs
- Superset of configurations

Expectations on holdover performance

5G air interface alignment Carrier aggregation	**±130 ns to ±1.5 µs across radios**
TSN Networks Industrial Networks Automotive Networks	**1 µs end to end**
Financial Networks	**400 ns – 1 µs**
Data Center Networks	**5 µs (OCP-TAP)**

Methods of achieving holdover

GNSS based reference

- Is most common primary source of reference

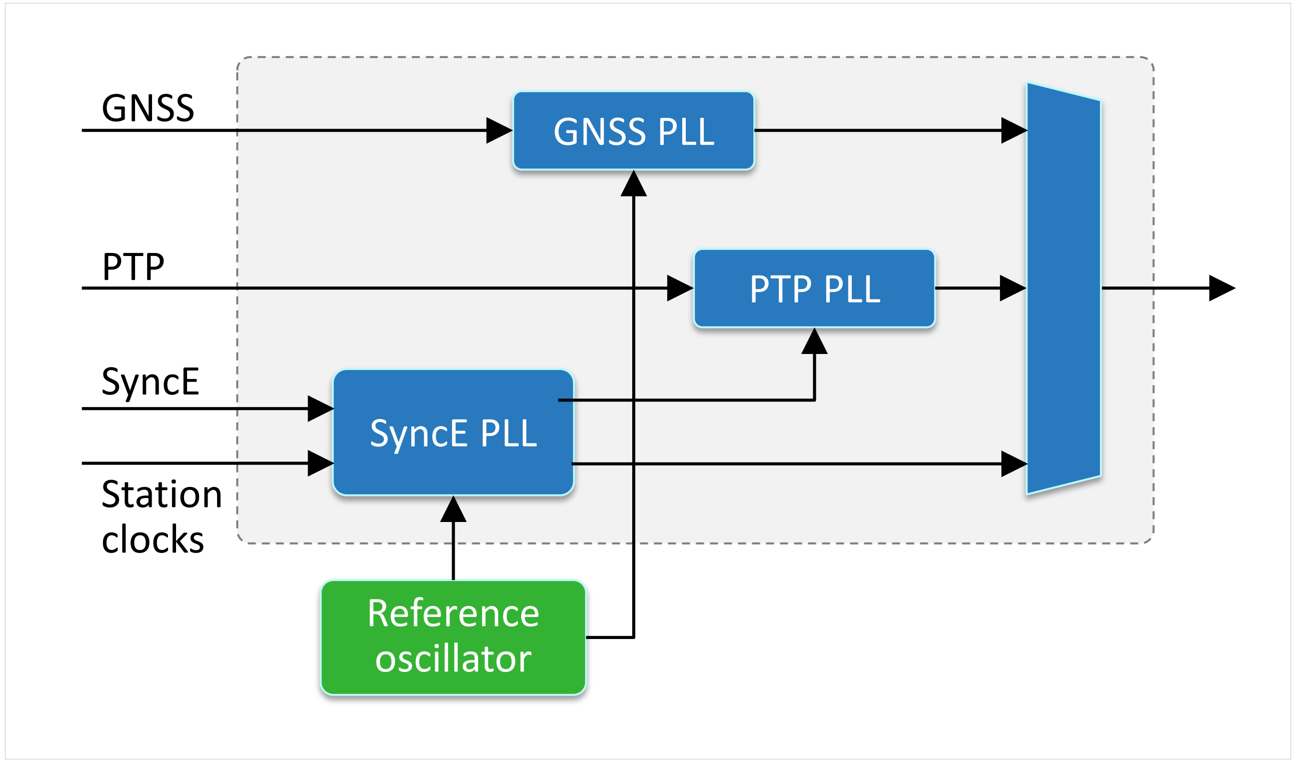
Holdover in various forms

- PTP holdover,
- SyncE holdover
- Oscillator Holdover

Oscillator holdover

- Default backup

Typical servo implementation diagram



The theory and reality

Phase Holdover At Time (t): $x(t) = x_o + (f_o + \text{average}(\Delta f_{env} + \Delta f_{HT} + \Delta f_{RW}))*t + ½* \Delta f_{age} * t^2$

x_o= Initial phase offset
fo: The initial fractional frequency offset (ppb)

The "Servo Error"

$\Delta f_{Age:}$ Systematic deviation over time

$\Delta f_{HT:}$ Effect of hysteresis on holdover

Δf_{env}: sum total of the changes in frequency (ppb) due to environmental factors (including temperature, input voltage, output loading, pressure, humidity, acceleration etc.)

Primary is temperature changes

Δf_{RW}: Random frequency noise not associated with environmental effects or long term aging
Aging: The long term change in frequency over time (ppb/day)

from ADEV characteristics

Additional factors affecting holdover

Micro Jumps	Short jumps on frequencies caused by the resonators and construction
Shock	Causes one time frequency spikes
Vibration	Causes frequency deviation for the period of vibration

Traditional methods of extension

Methods

Temperature characterization

Use temperature sensors near the oscillator and study the behaviour across temperature

Estimating hysteresis

Use the temperature characterization data to estimate hysteresis

Ageing measurement

Use ageing behaviour

Estimate random behaviour

Use the generalized numbers provided by oscillator manufacturer

Challenges

Operationally intensive

- Temperature cycling individual equipment to recover frequency characterization over temperature

Separating components

- Extract ageing along when temperature change involved
- Ageing random behaviours when change related to ageing involved

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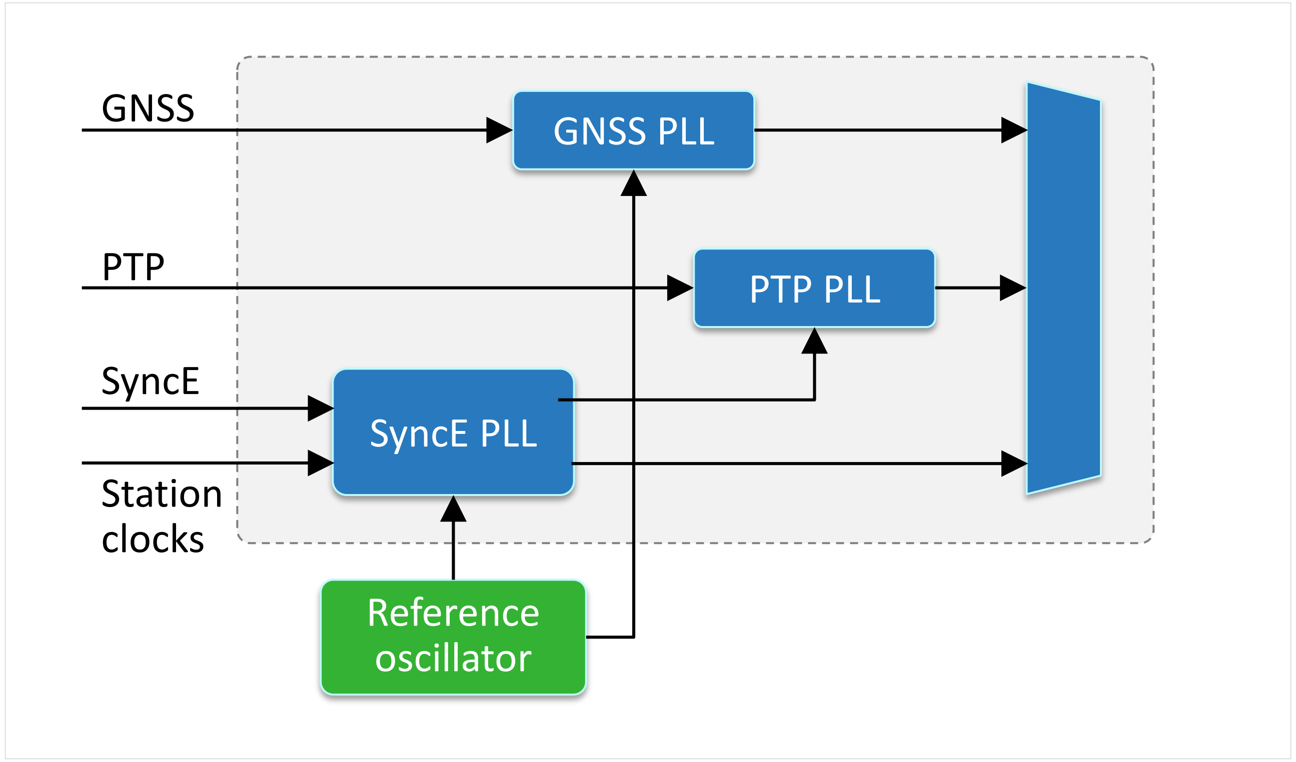
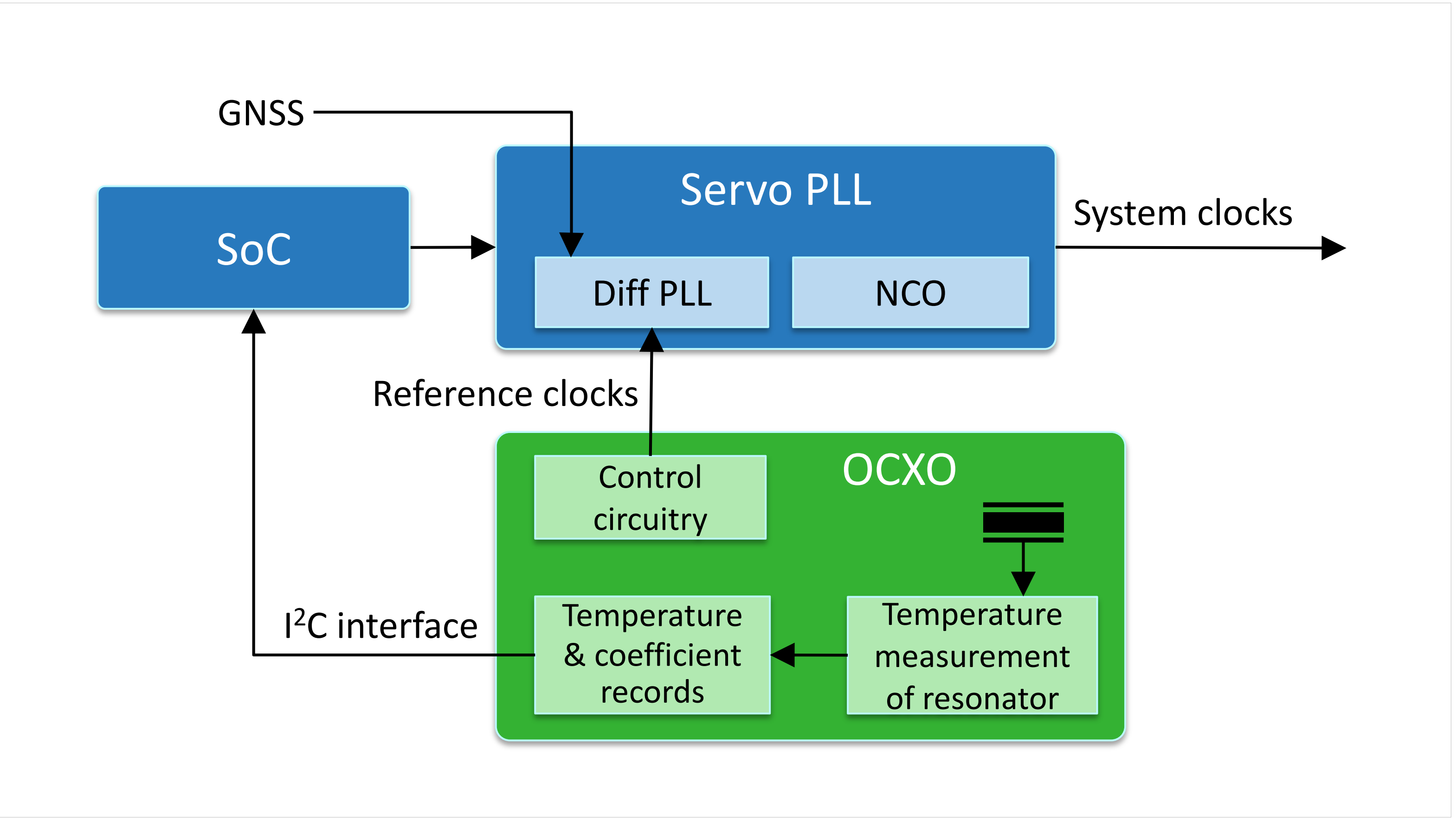


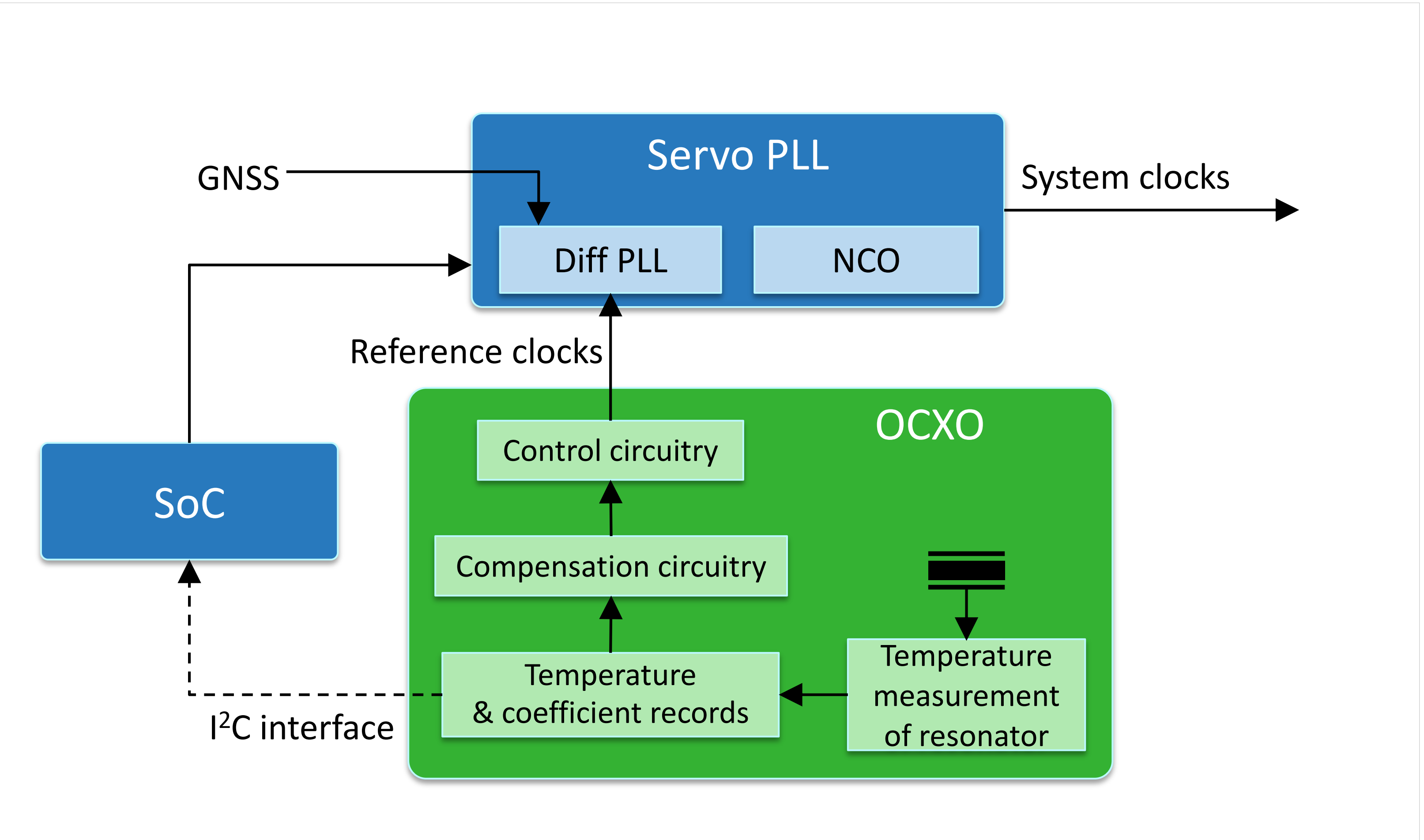
OCXOs with temperature coefficients

Frequency references providing frequency coefficients of temperature change



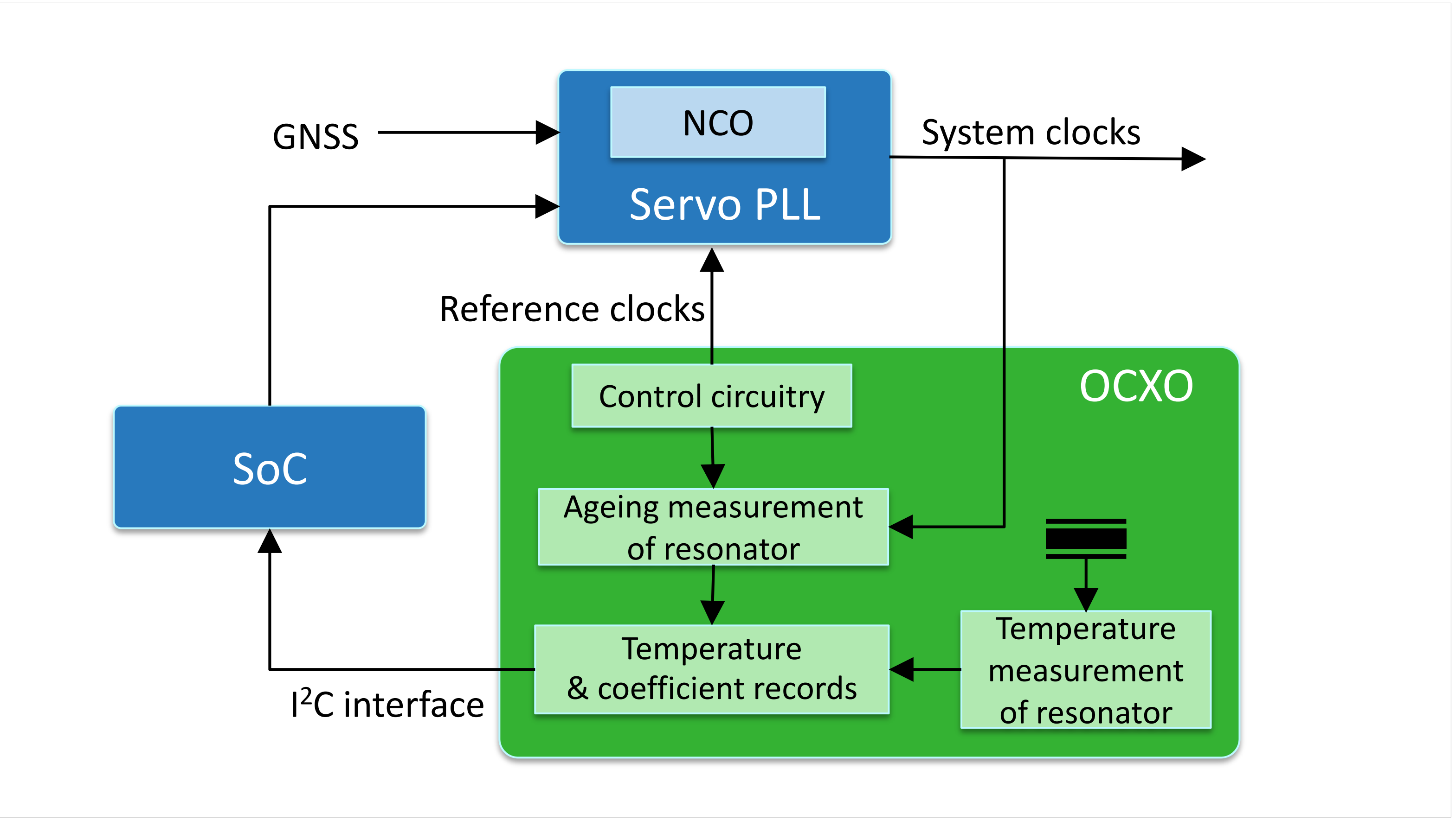
SMART OCXOs

OCXOs provides dynamic “post compensation” of temperature effects



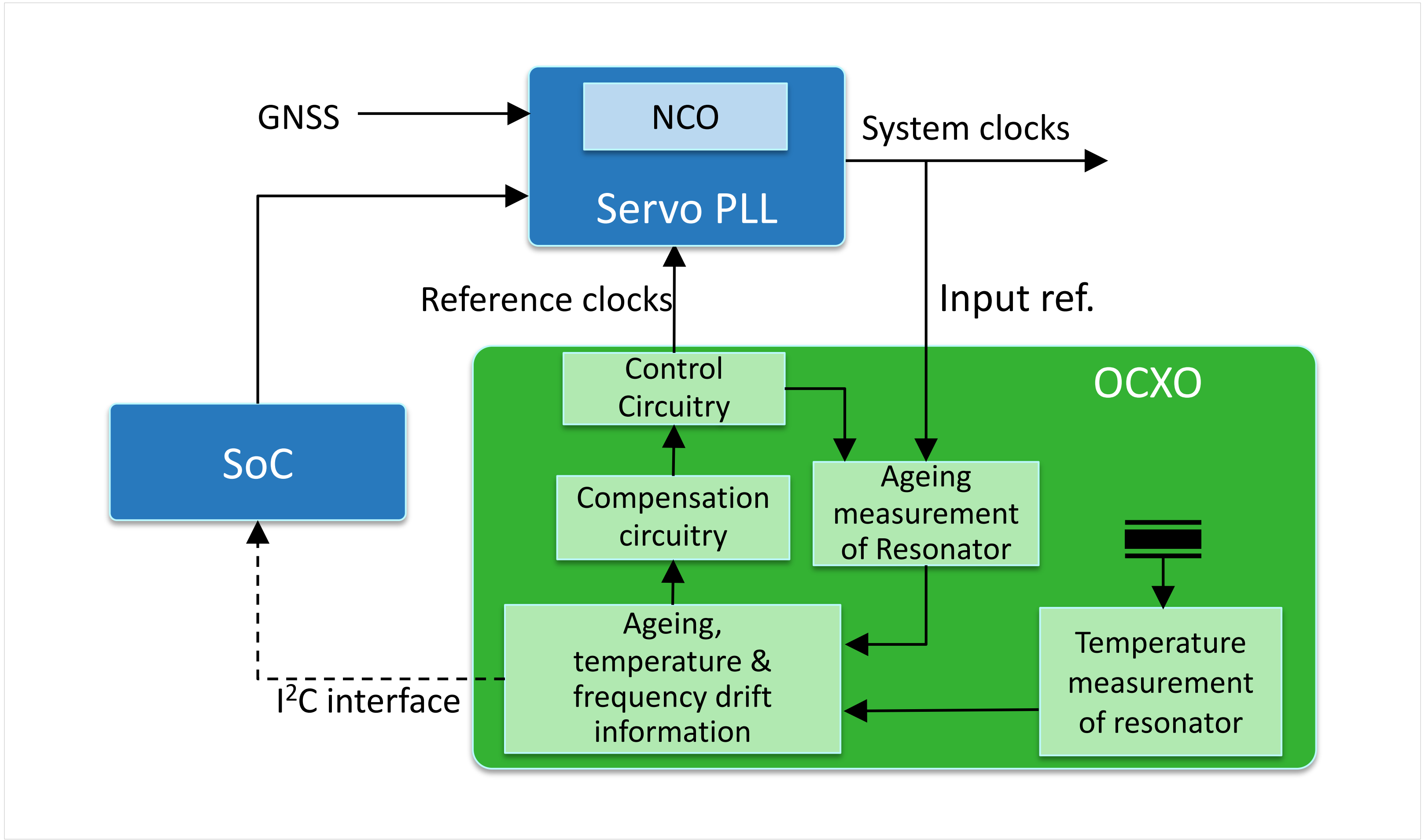
OCXOs with error frequency outputs

Frequency references providing frequency coefficients of temperature change



Holdover oscillator – PPS referenced

Frequency references providing frequency coefficients of temperature change



Challenges

1 Reasonable size

25 x 22 mm oscillators are industry standard

2 Common crystal resonator

High reliable and good performance HC43 resonator

3 Manufactural thermal package

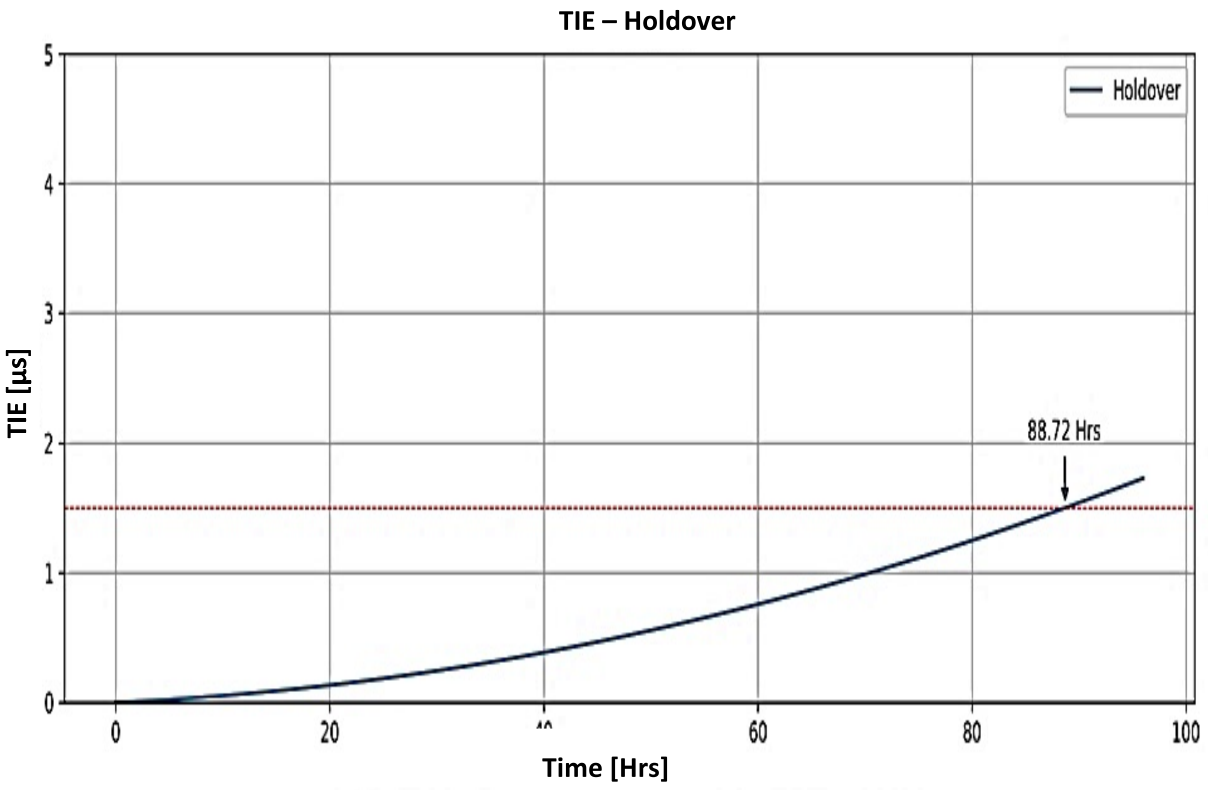
Special designs

Avoiding double ovens

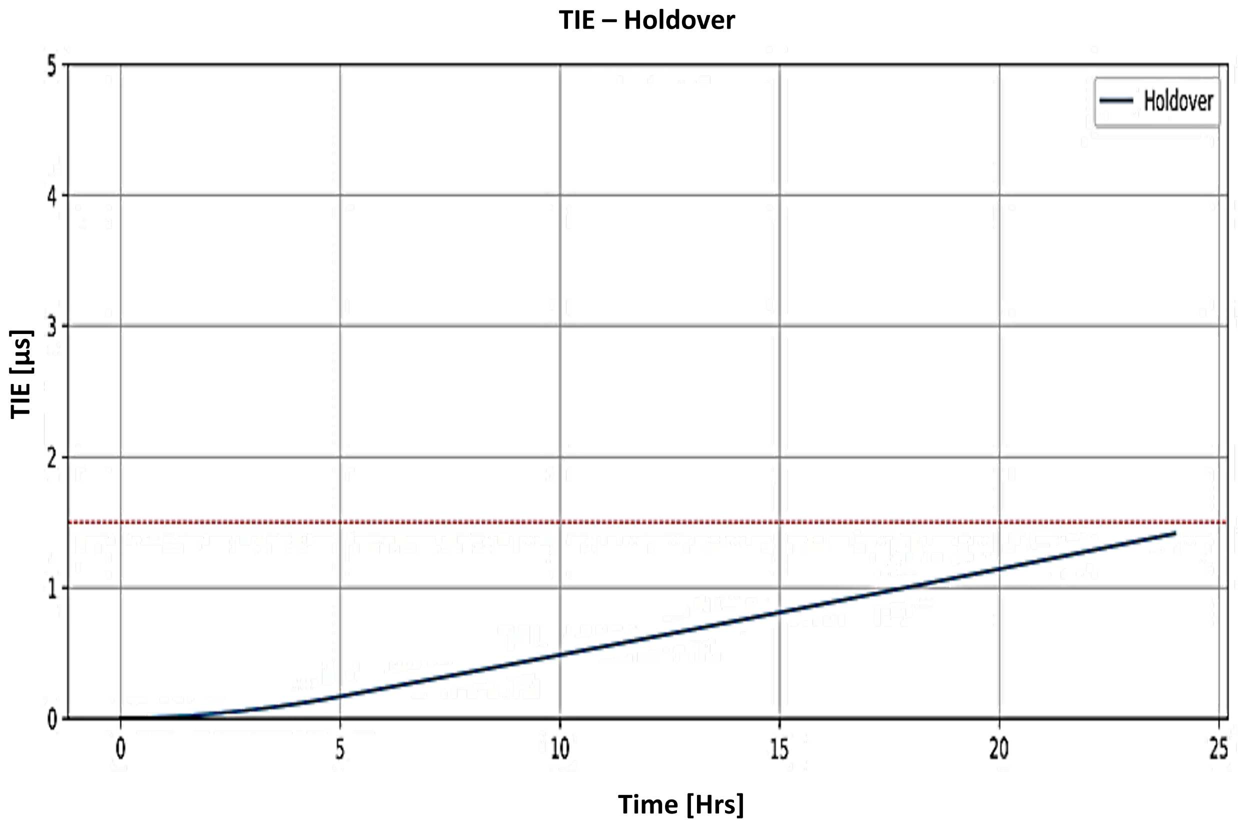
4 Testing capabilities

Custom testing flow for mass manufacturing

24-hour holdover – ROD2522S2



Constant temperature: 1.5 µs / >88 hrs



4°C temperature ramp at 0.8°C/hour rate >24 hrs

Summary

- Holdover is increasingly prominent in new networks
- GNSS vulnerability is real
- Various deployment techniques with oscillators
- Temperature out, frequency error out and integrated devices
- 24-hour holdover devices are possible
- On a 25 x 22mm industry standard package

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