Test Methodology for Measuring and Specifying Holdover in Industry Standards

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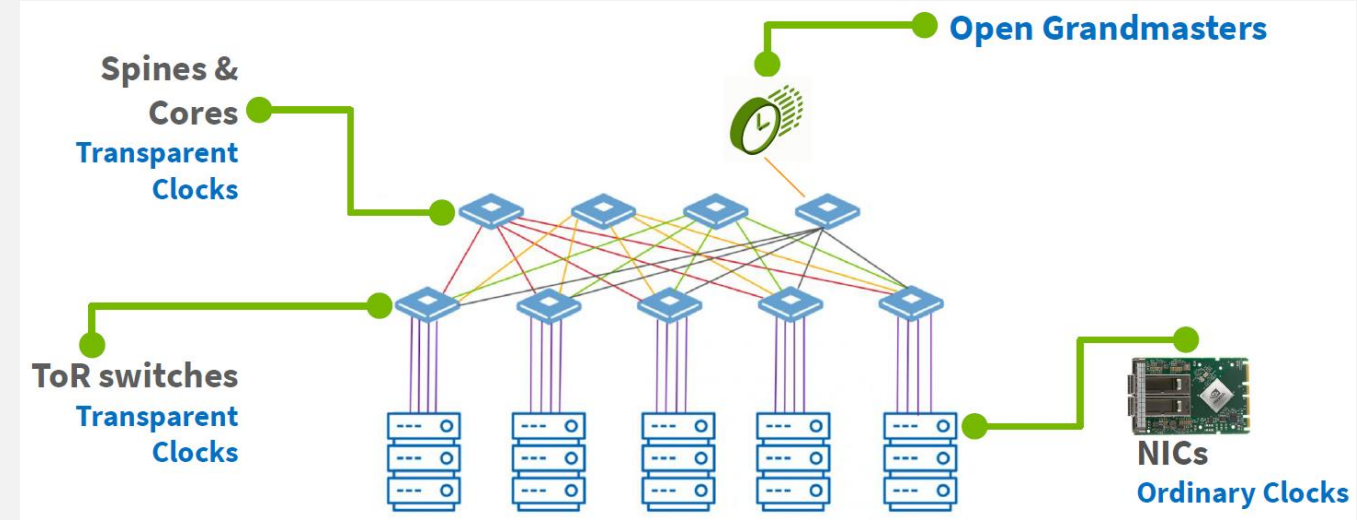
Agenda

- OCP-TAP Introduction
- Oscillator Class Specifications
- Holdover Test Method

Oscillators in the Network



Oscillator Examples

Node	Oscillator
Grandmaster (GM)	Atomic, OCXO
Transparent Clock (TC)	XO
Boundary Clock (BC)	OCXO, TCXO
Ordinary Clock (OC)	TCXO, XO

Simplify Oscillator Selection

- Problem
  - Difficult to understand 1588 performance from oscillator datasheet
  - Difficult to understand holdover performance of oscillator
  - Difficult to select oscillator for a given use case
- Goals
  - Simplify oscillator selection
  - Design predictable IEEE 1588 performance
  - Compare oscillator holdover in transparent, apples-to-apples, way
- Solution
  - Create oscillator classes for different use cases & performance levels
  - Standardize holdover testing

Use Case Scenarios

Node	Class	Equipment	Environment
GM	G1	Open GM	Traditional DC
GM	G2	Open GM	Edge DC for O-RAN
GM	G3	Open GM	POP edge DC
GM	G4	NIC	Traditional DC
BC	B1	ToR switch	Traditional DC
BC	B2	NIC	Edge DC for O-RAN
BC	B3	Server motherboard	Edge DC for O-RAN
TC	T1	Leaf/Spine switch	Traditional DC
OC	F1	NIC	Traditional DC
OC	F2	NIC	Edge DC for O-RAN
OC	F3	Server motherboard	Traditional DC
OC	F4	USB stick	Traditional DC

Done

Oscillator Class G1 – Grandmaster

1 Requirements for Class G1 Oscillator, Normative

Table 1. Standard data-center environment without synchronous Ethernet, see use case GM-A

Parameter	Symbol	Requirement
Ambient temperature (pick 1)	T_a1	-10°C to 70°C
	T_a2	0°C to 45°C
g-sensitivity	F_g	< 0.5 ppb/g
Frequency stability over temperature	F_stab	≤ ±0.5 ppb[1]
Frequency stability over temperature slope	dF/dT	≤ ±7 ppt/°C[2]
Allan deviation, Tau=100s	ADEV	≤9e-12
Daily aging	F_1d	≤ ±0.035 ppb/day[3]
Training time before entering holdover	t_h	< 12 hours
24-hour holdover	F_hold_24h	≤ ±1.4 µs in 24 hr[4]
1 hour holdover	F_hold_1h	≤ ±250 ns in 1 hr[4]
Jitter	J_pp	≤ 1 ns peak-peak[5]
Additional design requirements	ADR	List manufacturer recommendations[6]

Source:

"Requirements Document for OCP-TAP Oscillator Classes"

https://www.opencompute.org/documents/ocp-tap-oscillator-spec-jan-8-2022-docx-pdf

Specify Holdover Test Params

Use Case Dependent

- Holdover time, τ_h
- Thermal profile – target starting temperature, ramp rate, soak time
- Operating ambient-temperature range
- Ambient temperature to measure aging
- Ambient temperature to measure frequency versus time trend
- Acceptable probability of error, P_E, required by system
- Training time before entering holdover, $\tau_{Training}$
- Sample-unit population, N, and distribution
  - For example: 10 random units from each of 3 lots, each with a different process and assembly
- Trial population, M, to capture random variations per unit
- Whether the system compensates for aging

Proposed Holdover Test Method

Use Case Independent

Measure

- Frequency stability over the specified operating ambient temperature range
- Frequency versus time at the specified ambient temperature

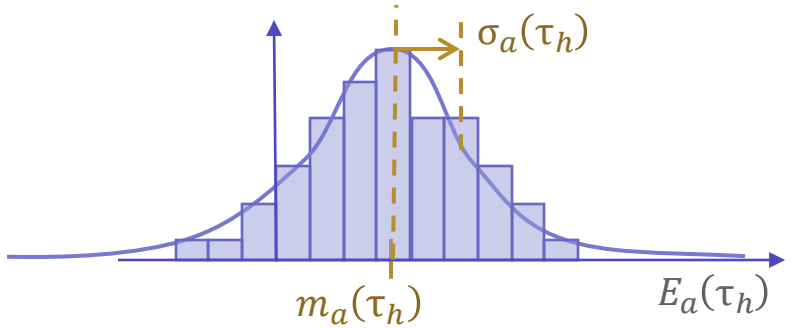
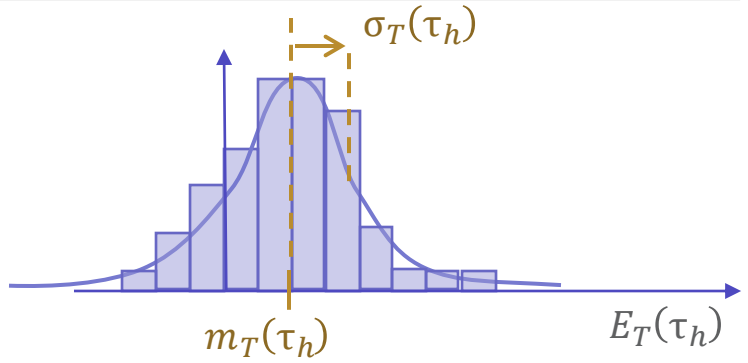
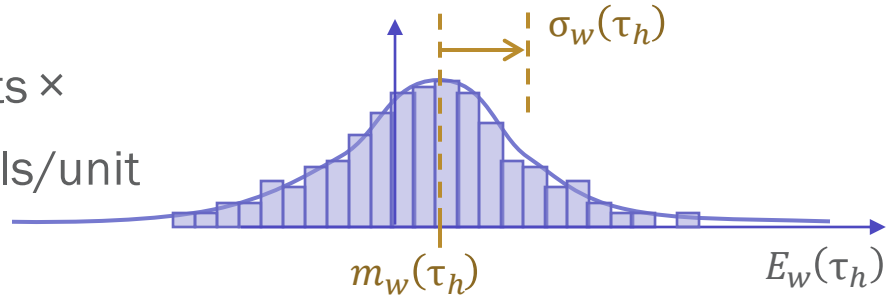
Compute

- Extract daily aging, thermal drift and wander from measured data
- Max time error $E_{max}(\tau_h, P_E)$ up to holdover time $t{=}\tau_h$ and derived from measured Gaussian distributions for
- Aging – $m_a(\tau_h)$, $\sigma_a(\tau_h)$
- Thermal drift – $m_T(\tau_h)$, $\sigma_T(\tau_h)$
- Wander – $m_{\mathrm{w}}(\tau_h)$, $\sigma_{\mathrm{w}}(\tau_h)$

Report

- $Emax\ (\tau_h, P_E)$ versus holdover time, $t{=}\tau_h$
- Vendor-specific test conditions and restrictions needed to reproduce results

Statistical Model for Noise

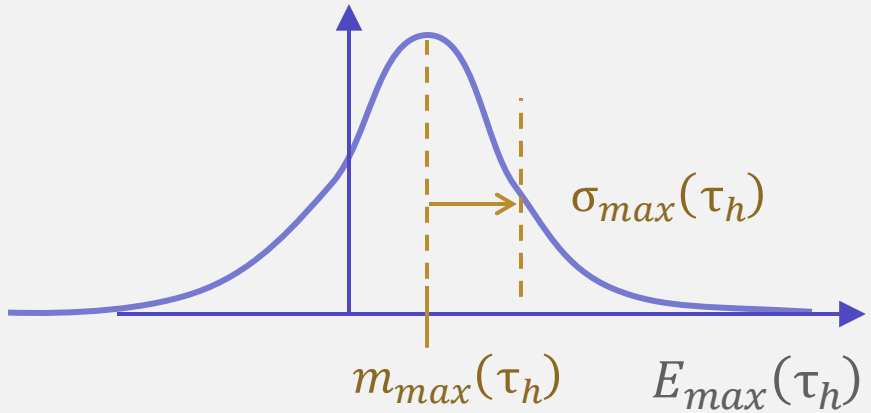
	POPULATION	TIME ERROR HISTOGRAM
Aging	N units	
Thermal Drift	N units	
Wander	N units × M trials/unit	

TOTAL TIME ERROR

$$m_{max}(\tau_h) = m_a(\tau_h) + m_T(\tau_h) + m_w(\tau_h)$$

$$\sigma^2_{max}(\tau_h) = \sigma^2_a(\tau_h) + \sigma^2_T(\tau_h) + \sigma^2_w(\tau_h)$$

Distribution of Total Time Error up to time τ_h



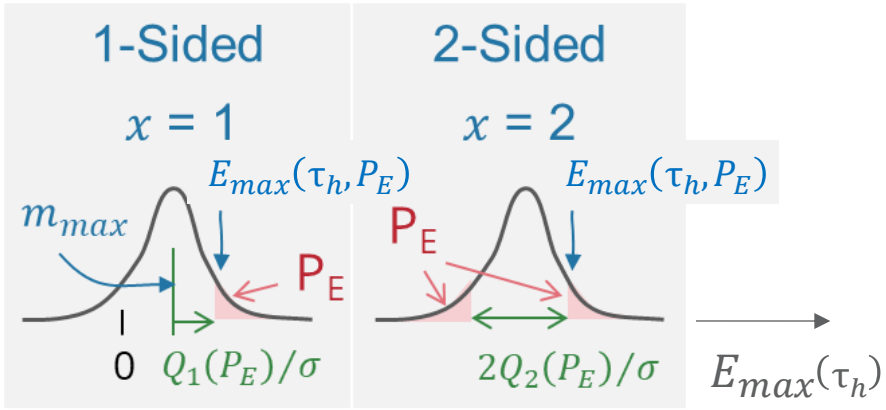
Compute Time Error in Holdover

$$E_{max}(\tau_h, P_E) = m_{max}(\tau_h) + Q_x(P_E)\sigma_{max}(\tau_h)$$

Q converts RMS to Peak for a specified error rate, P_E

2 Possibilities

$|m_{max}| \gg 0$ $m_{max} \cong 0$



1-P_E	$Q_1(P_E)/\sigma(\tau_h)$	$Q_2(P_E)/\sigma(\tau_h)$
0.682689	0.475	1.000
0.954499	1.690	2.000
0.997300	2.782	3.000
0.999002	3.091	3.291
0.999900	3.720	3.891
0.999937	3.833	4.000
0.9999990	4.754	4.892
0.9999994	4.865	5.000

Interpretation

- All units shipped will not exceed $E_{max}(\tau_h, P_E)$ up to holdover time τ_h with at most probability of error P_E

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Contribute to OCP-TAP

- Workstreams, *https://ocptap.com*
  1. Open Time Server
  2. PTP Profile
  3. Precision Time APIs
  4. Oscillators
  5. PTP Servos
  6. Instrumentation and Measurement
  7. Time Sync Reliability
- Contact workstream lead shown on wiki page
  - *https://www.opencompute.org/wiki/Time_Appliances_Project*
- Subscribe to mailing list
  - *https://ocp-all.groups.io/g/OCP-TAP*

Thank You

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