Outline

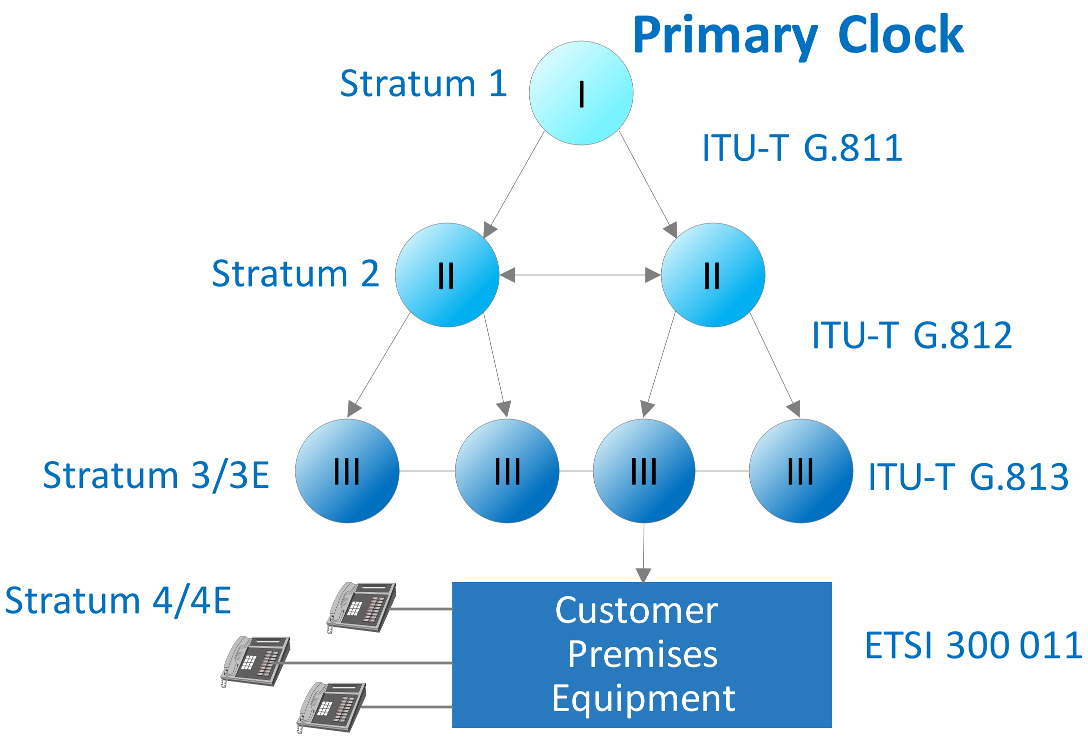
1

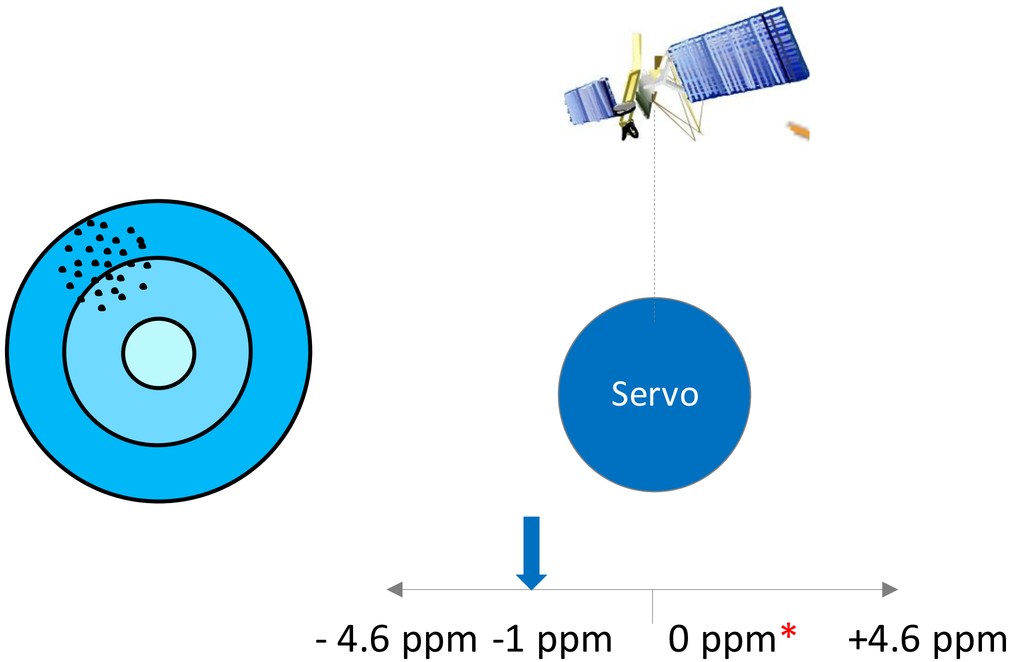
Oscillators

- Oscillators in synchronisation
- Oscillator selection for clocks

Oscillators in synchronisation

- **Synchronization is hierarchical**





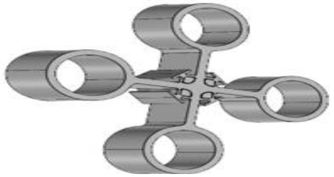
* **ppm** – **p**arts **p**er **m**illion

- **Local reference in systems**

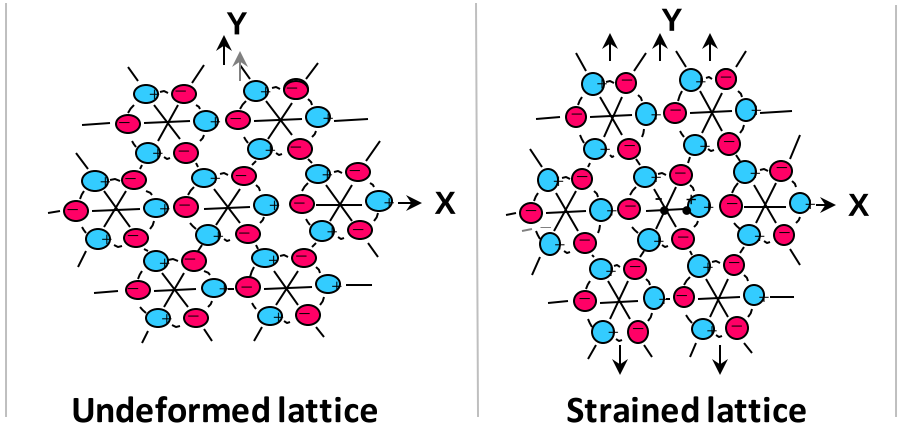
- **Stability requirements**

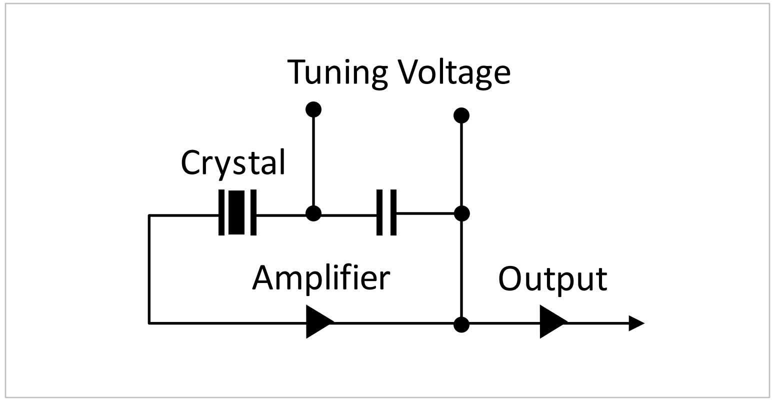
Oscillator technologies

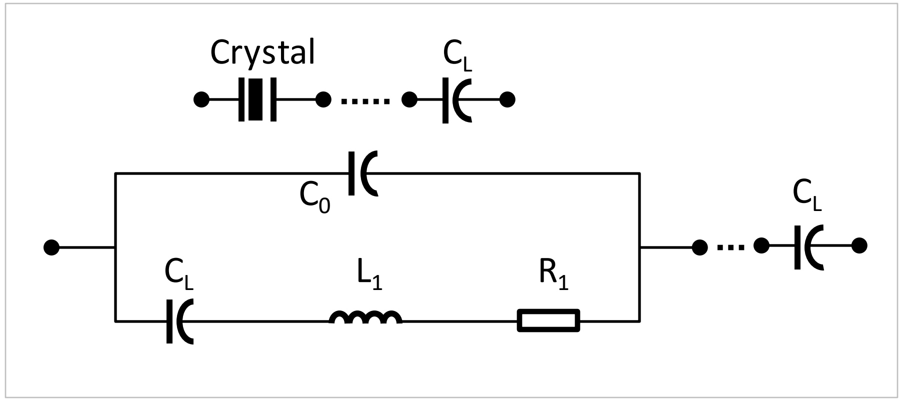
- Various technologies
- Quartz based oscillators
- Other technologies



- Piezo Electric Effect





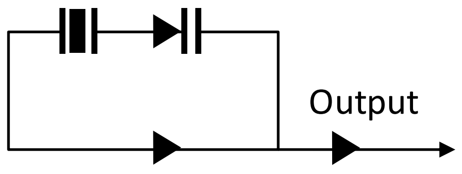


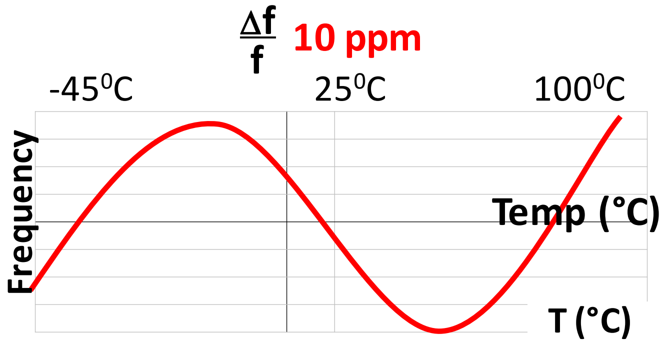
Ballato, "Doubly rotated thickness mode plate vibrators," in Physical Acoustics, Vol. XIII, pp. 115-181, Academic Press, 1977.
John R. Vig Quartz Crystal Resonators and Oscillators For Frequency Control and Timing Applications - A Tutorial April 2012

Types of oscillators

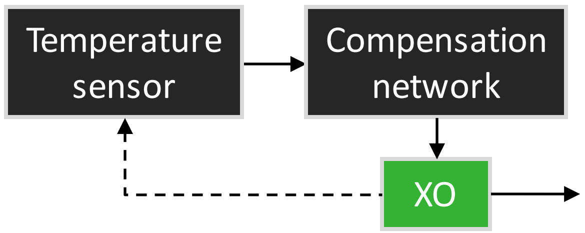
Oscillators are susceptible to temperature variations

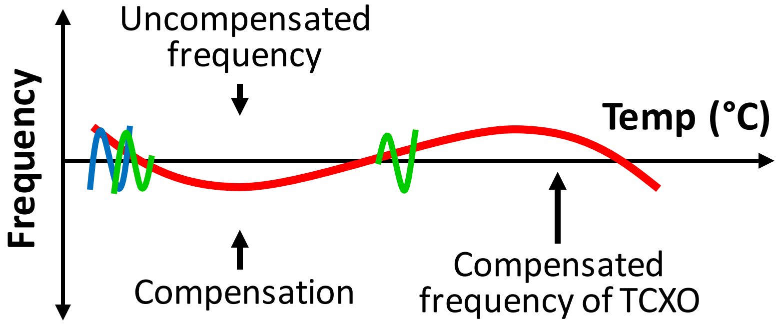
XOs

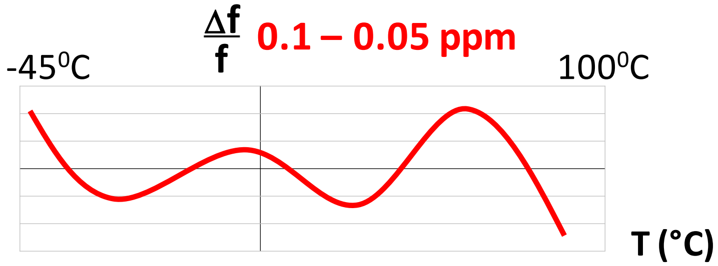




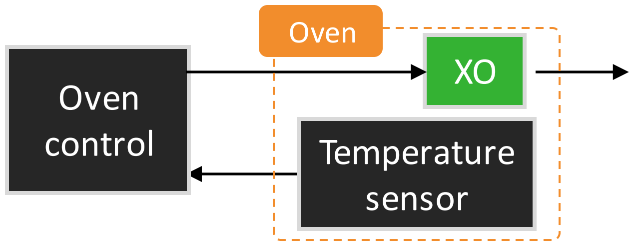
TCXOs – temperature compensation

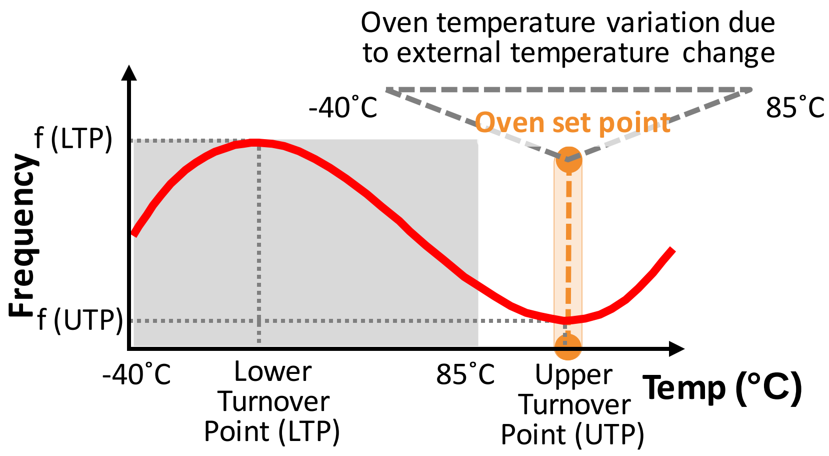


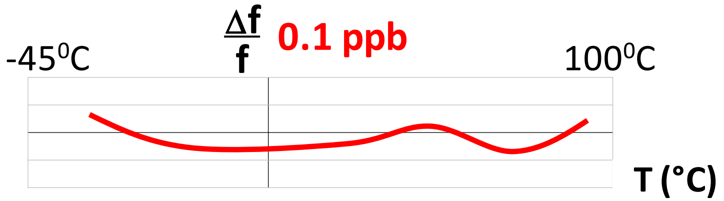




OCXOs – oven control

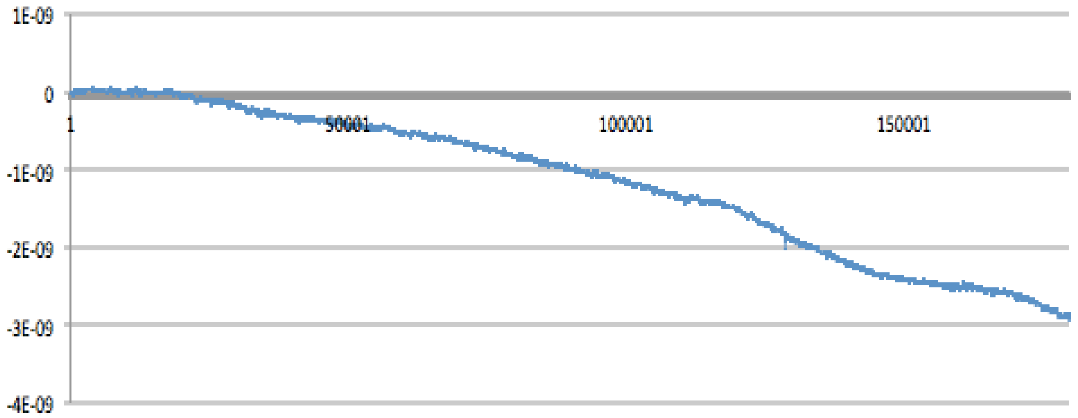




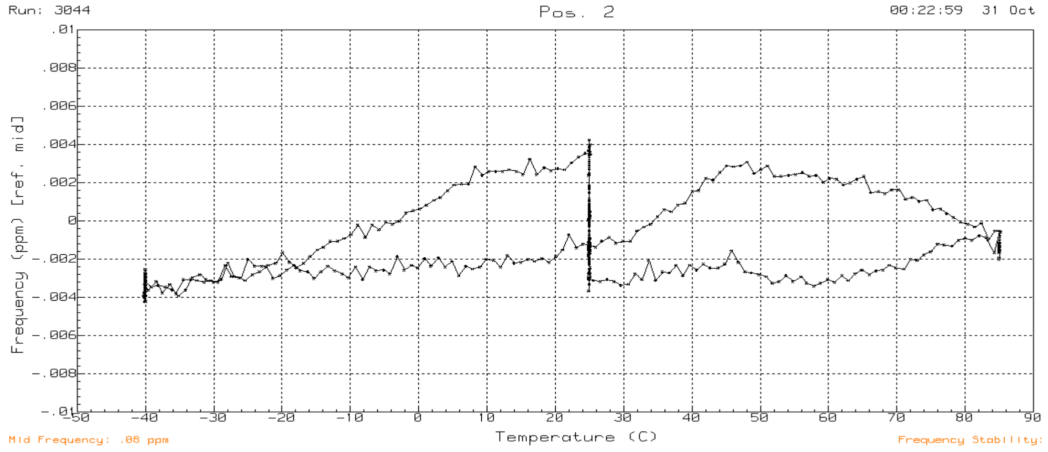


Influences on oscillators

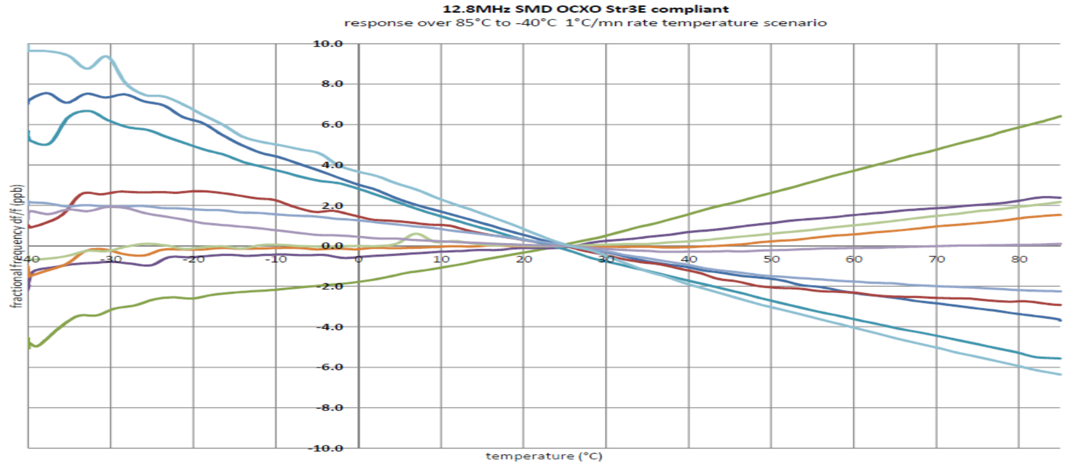
Aging effect



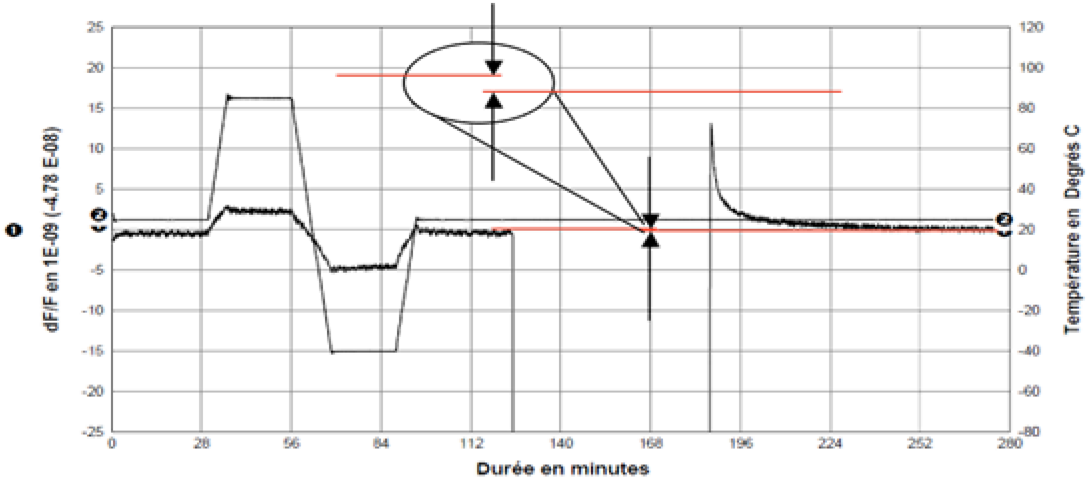
Hysteresis effect



Temperature Effect

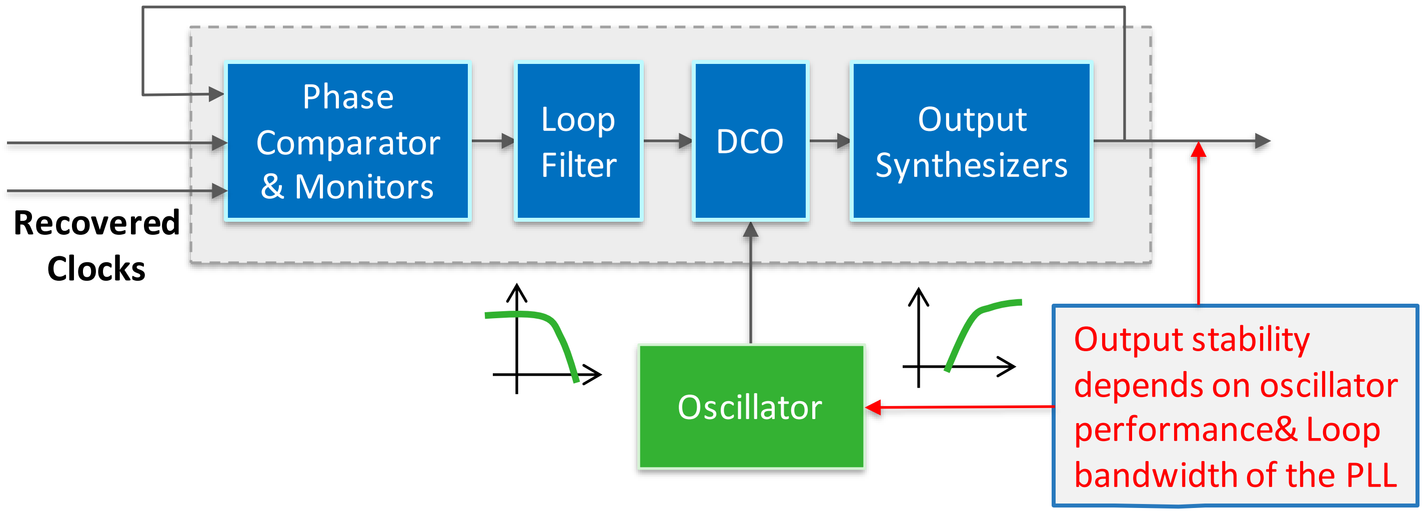


Retrace effect



Oscillator selection for clocks

Cuts of the crystal



Impact of Oscillators

- Oscillators present a high pass effect to the output
- As the loop bandwidths become narrower, output corrections are more infrequent
- Variations on the reference oscillator reflect at the output

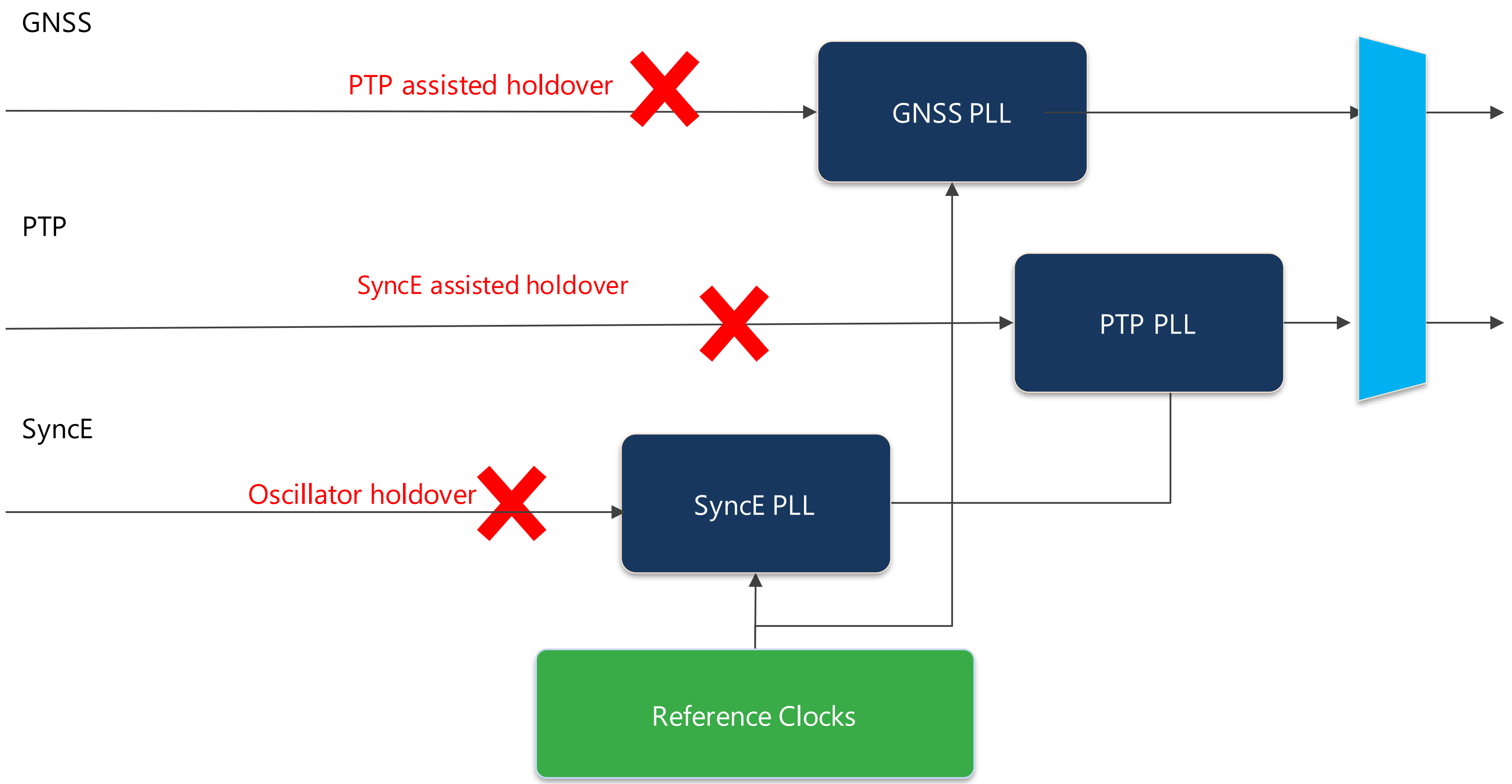
Loop bandwidth	10 – 100 Hz	1 – 10 Hz	0.1 – 1 Hz	10 – 100 mHz	1 mHz	<1 mHz
Recommended oscillator temperature stability	0.5 – 1 ppm	0.1 – 0.3 ppm	0.05 – 0.1 ppm	20 – 50 ppb	5 – 10 ppb	1 – 5 ppb

Oscillator selection

Oscillator requirements are based on

- **Free Run →**
  Overall oscillator stability for 10/15/20 years, all causes included
- **Loop bandwidth →**
  Support for loop bandwidth at required output error, at constant temperature and at variable temperature
- **Frequency Vs temperature performance →**
  This forms part of the wander generation and holdover requirement of the standards
- **Ageing performance →**
  This forms part of the wander generation and holdover requirement specifications
- **Phase noise, temperature sensitivity, Allan deviation, shock & vibration performance →**
  Other oscillator effects depend on the application

Holdover Scenarios

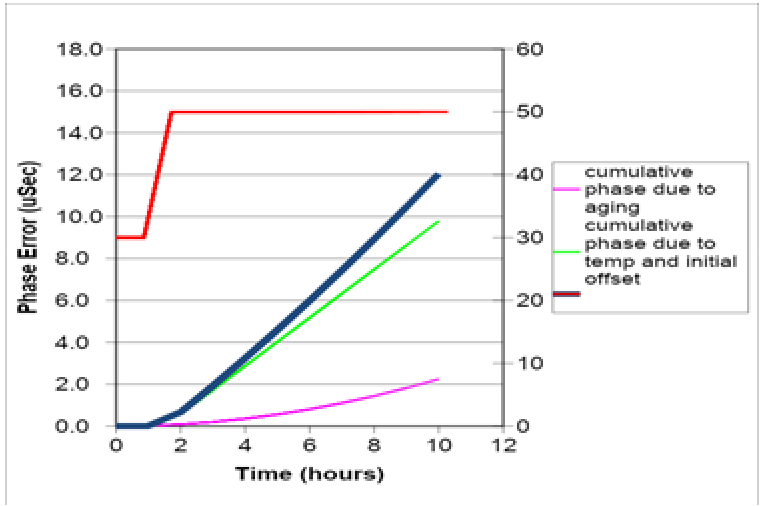


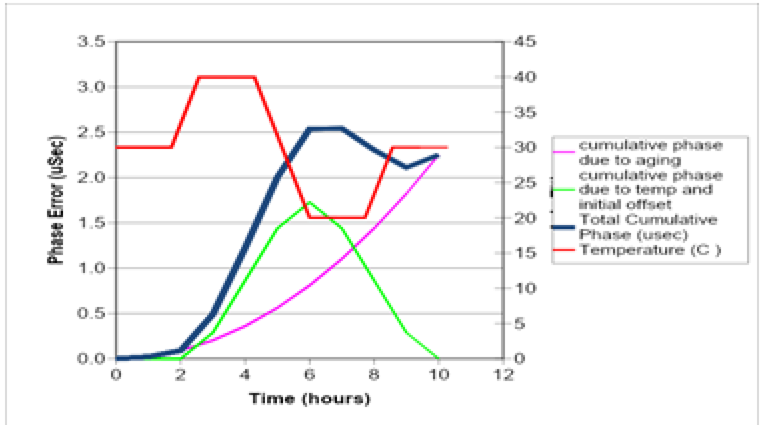
Worst Case Phase Holdover

Worst Case Phase Holdover At Time (t):

$$x(t) = x_o + (f_o + \text{average}(\Delta f_{env} + \Delta f_{RW}))*t + \tfrac{1}{2}*\text{aging} * t^2$$

x_o= Initial phase offset
fo: The initial fractional frequency offset (ppb)
Δf_{env}: The total change in frequency (ppb) due to environmental factors (temperature, input voltage, output loading, pressure, humidity, acceleration etc.)
Δf_{RW}: Random frequency noise not associated with environmental effects or long term ageing
Ageing: The long term change in frequency over time (ppb/day)





Summary

- Oscillators are fundamental building blocks of clocks
- Temperature compensation and oven control and methods used to improve stability of clocks
- As the loop bandwidth of the systems decrease, higher stability oscillators to be used to have a certain level of output stability
- Wander generation and holdover are key aspects of oscillator selection in systems