Synchronisation for Packet Networks

Introduction

Packet based synchronisation is finding its importance in many applications because of its bi-directional information exchange capabilities. Traditional physical layer synchronisation methods were limited to frequency synchronisation whereas protocol based synchronisation can achieve frequency, phase and time synchronisation. The application areas are including but not limited to Telecommunication Networks, Cellular Mobile Systems, Access Networks like Cable, DSL and Fibre, Power Grid systems, Enterprise Networks, Video Broadcast Systems.

One of the key areas where packet based synchronisation is being deployed is the cellular mobile networks, particularly with the evolution of 5G networks. 5G exploits the spectral efficiency to the full when the systems are supporting TDD mode, where phase alignment between base stations is a key requirement. Even in FDD mode, advanced features like CA, JT, eMBMS and CoMP are possible with phase alignment between stations. Location Based Service applications are only possible with this phase alignment. Traditionally, phase alignment has solely relied on GNSS based synchronisation, however, GNSS vulnerabilities and geographical limitations challenges this reliance. Overcoming these limitations, Packet-based synchronisation becomes an alternative or assistive technology for GNSS synchronisation.

Choosing the Optimal Oscillator for Packet Based Application

Telecom synchronisation has moved onto packet transport based synchronisation technologies. There are a number of clock types defined by Standards bodies which depend on the type of networks, (unaware, full timing support and partial timing support) network elements (master, slave, and boundary) and clock types (filtered or transparent). Standards defined clock types also depend on whether they have for physical layer clocking support (with or without SyncE) and assistance (being a backup for a GNSS reference). These defined clock types can support either frequency only, or time, phase and frequency together. Often, one type of equipment is required to support many clocking options with software configuration.

All these clocks need a local reference time source to support the implementation of the servos that filters reference sources. The filter bandwidths range from <1 mHz (unaware network PEC-F clocks) to all the way 10 Hz (EEC Option 1). For a specific output wander generation performance under variable temperature, the lower the bandwidth of the servo system, the better oscillator with temperature stabilities and sensitivities are required.

Oscillator requirements are determined by their ageing and temperature stabilities, as they contribute towards the target holdover of a given packet clock. With current performance levels, although a TCXO can theoretically address fully aware networks in limited cases, real world implementations comprise a wide range of equipment and therefore require a Stratum 3E OCXO to handle a superset of standards requirements.

At the same time, applications are driving the node error to be lowest as possible (proposed node error values of 5ns) to support upcoming deployment scenarios such as the front-haul network of 5G cellular networks. Such applications demand still higher stability clock references.

Packet Network Synchronisation Solutions

Oscillators		Stability (-40 to 85°C)	Ageing	Phase Holdover (1.5 µs)	Supported Bandwidth
Pluto+™ (5x3, 7x5)		±100 ppb	< ±1 ppm/year	–	100 mHz
Neptune™ (5x3, 7x5)		±50 ppb	< ±1 ppm/year	–	100 mHz
Mercury+™ (9x7)		±10 ppb	< ±1 ppb/day	15 min	3 mHz
Mercury+™ (14x9)		±5 ppb	< ±1 ppb/day	1 hour	1 mHz
ROX S4 (25x22, 25x25)		±5 ppb	≤ ±0.5 ppb/day	4 hours	1 mHz
ROX S3 (25x22)		±1 ppb	≤ ±0.3 ppb/day	8 hours	0.3 mHz
ROX T2 (38x27, 52x42)		±0.25 ppb	≤ ±0.2 ppb/day	24 hours	0.1 mHz
ROX T1 (52x52)		±0.05 ppb	≤ ±0.1 ppb/day	48 hours	<0.1 mHz

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Medium Term Stability Challenges for Oscillators used in IEEE 1588

In packet-based synchronisation implementations, the local synchronised oscillator is moving from a physical layer-based phase or frequency locked loop, to a time locked system via secondary layer protocols.

Oscillators present themselves as high pass filters in the control loop, thus smaller loop bandwidths can mean that the medium- term stability performance of an oscillator is important to the overall system performance. Effectively the oscillator's stability performance is now dominated by environmental changes during these 'medium-term' time periods.

The oscillator stability over the medium-term (minutes to hours) is either poorly characterised or has not been accounted for at all, since the stability under these conditions is covered indirectly by other oscillator / system specifications.

Historically, there have been only two 'oscillator / lock bandwidth' combinations, namely Stratum 3 and Stratum 3E.

However, packet based implementations introduce other loop bandwidths depending on the network scenario and thus stability at each loop bandwidth becomes important.

The non-stationary nature of Packet Delay Variation (PDV) imposes new requirements for the local oscillator. Loops operate with lock bandwidths in the 10 to 0.1 mHz region (time constant 1600 s) to filter the wander introduced by PDV. System specifications for frequency stability, holdover requirements for frequency and if required, phase error, will determine the requirements for oscillators.

With Stratum 3E oscillators however, because of the very high stability required for the variable temperature stability requirement (i.e. ±5 ppb over a relatively wide temperature range), small changes in temperature will not affect the TDEV and MTIE even with a 1 mHz lock bandwidth, and a time constant of 160 s.

IEEE 1588

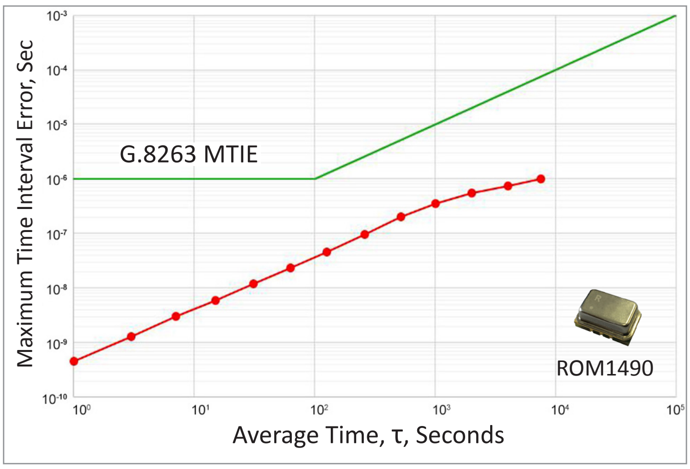
MTIE Performance for Rakon's OCXOs

Rakon's ASIC based and conventional OCXOs are designed for bandwidths of 1 mHz down to 0.1 mHz and below and for very tight holdover performance. These products are designed for the most stringent system requirements. The Mercury™ and Mercury+™ ASICs have made possible the smallest (14 x 9 mm and 9 x 7 mm), lowest power consuming (350 mW) and most reliable (FIT of <50) OCXOs in the industry, with temperature stabilities between ±5 to ±50 ppb. LTE-A and LTE-TDD Small Cell technologies require tight phase accuracies (±1.5 µs) and applications like Location Based Services (LBS) are driving accuracy requirements to even more stringent values (~ 500 ns).

For systems that do not require holdover, oscillators that are compliant to G.8263 specifications may still provide the wander filtering necessary to meet the TDEV/MTIE requirements. The challenge for the system designer is to assess which oscillator will work at which lock bandwidth and still meet the implied TDEV/MTIE requirements in locked conditions. System designers must also assess which oscillators are needed to provide adequate holdover for the specified duration of time required by the application. This is where Rakon can help!

MTIE Performance: Mercury+™ IC OCXO

-40 to 85°C (1°C/min) 1 mHz loop filter



MTIE Performance: Conventional OCXO

-40 to 85°C (10°C/hour) 1 mHz loop filter