

### Introduction

Networks are transitioning from circuit switched systems to packet switched systems to increase efficiency, flexibility and cost effectiveness. Data for time critical services such as audio and real time video, is transported through inherently asynchronous Packet Networks. These networks require timing over packet technologies such as IEEE 1588 to be implemented, in order to support network synchronisation. The requirements for packet based synchronisation designs are posing challenges to the methods previously used.

Rakon has characterised various types of oscillators under changing environmental conditions that meet the technical requirements of IEEE 1588. Rakon offers a wide range of oscillators that meet a variety of IEEE 1588 application requirements.

### 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 limit 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.  $\pm 5$  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.



### Rakon Solutions for Packet Network Synchronisation

Model Code	Package Size	Frequency Range	Temperature Stability (-40 to 85°C)	Ageing	Time to Reach Phase Error Limit ( $\Delta t$ ) 1.5 $\mu$ s	Supported Bandwidth
OCXO: ROX-T2	52 x 52 mm 52 x 42 mm	5 to 15 MHz	$\pm 2$ ppb	$\leq \pm 0.07$ ppb/day	8 hours	0.1 mHz
OCXO: ROX-T3	38 x 27 mm	5 to 40 MHz	$\pm 1$ to 5 ppb	$\leq \pm 0.1$ ppb/day	4 hours	0.3 mHz
OCXO: ROX-S4	25 x 22 mm 14 x 9 mm	5 to 40 MHz	$\pm 5$ ppb	$\leq \pm 0.5$ ppb/day	4 hours	1 mHz
OCXO: ROM-E	20 x 13 mm 14 x 9 mm	10 to 50 MHz	10 ppb pk-pk	$< \pm 1$ ppb/day	20 minutes	1 mHz
OCXO: RFPO-45	9 x 7 mm	10 to 26 MHz	10 ppb pk-pk	$< \pm 1$ ppb/day	15 minutes	3 mHz
TCXO: RPT-J	7 x 5 mm	10 to 40 MHz	$\pm 100$ ppb	$< \pm 1$ ppm/year	-	10 mHz



# Synchronisation for Packet Networks

## Choosing the Right Oscillators for Each Application

At Rakon we have the expertise to help determine the best oscillator solution for a customer's system requirements. Choosing the right oscillator solution requires knowledge of the differential in frequency versus the differential in temperature ( $\Delta F/\Delta T$ ). Complete characterisation of the oscillator is defined by the operating temperature range, the temperature ramp rates and time domain analysis of measured data.

ITU – T has published requirements for clocks based on unaware packet networks – G.8263 based clocks. These clocks support frequency only operation but need very stringent MTIE and TDEV requirements. The G.8273.2 clocks support frequency, phase and time, but are primarily targeted at aware networks. Even though every node in the network supports the packet clocks, the dynamic time error requirement on these clocks demands high stability oscillators.

The MTIE requirements of 40 ns over 1000 s and over temperature, necessitate ovenised crystal oscillators of few ppb/°C temperature sensitivity. Rakon's IC based, highly reliable Mercury™/Mercury+™ oscillators are cost effective solutions for boundary and slave clocks.

There are a number of application scenarios which require partially supported networks with no synchronous ethernet synchronisation to support the PTP architecture, these implementations require still higher stability clocks. Rakon has OCXO solutions that can support stability levels of 1 ppb to 20 ppb, depending on the needs of the application.

## IC-based and Conventional OCXOs

**Mercury+™ IC OCXO:** Rakon's 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 30) OCXOs in the industry, with temperature stabilities between  $\pm 5$  to  $\pm 50$  ppb. The LTE-A and LTE-TDD Small Cells technologies require tight phase accuracies (1.5  $\mu$ s) and applications like Location Based Services (LBS) are driving the accuracy requirements to even more stringent values (~ 500 ns).

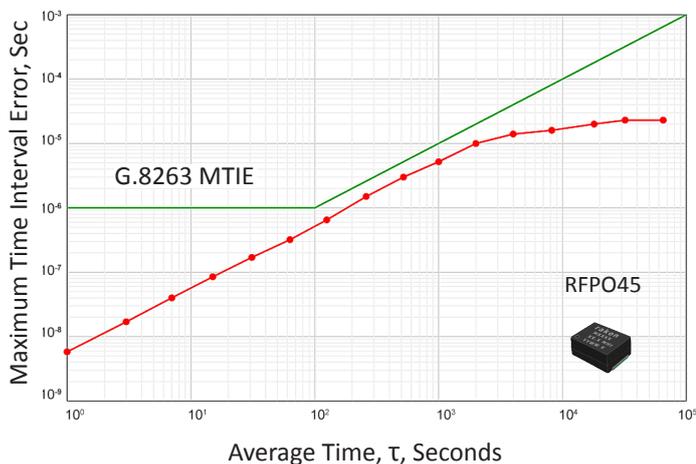
Mercury+™ OCXOs enable Small Cell applications that require short phase holdover (15 minutes to 1 hour under limited ambient temperature excursions) but with much smaller size and lower power consumption than traditional OCXOs.

**The 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.

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 (10°C/hour) 1 MHz loop filter



**MTIE Performance: Conventional OCXO**

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

