Introduction

This application note provides some basic guidelines when selecting the proper crystal oscillator (XO) to work with the Renesas family of Network Synchronization PLLs (ClockMatrix™, WAN-PLL™). A list of recommended oscillator vendors and part numbers are provided, and have been categorized based on applicable industry standards.

For a complete list of Renesas' Network Synchronization PLLs, refer to the Clock Synchronizers, Network Synchronization & PLLs page.

Key Oscillator Parameters

Frequency Accuracy

The frequency accuracy (or free-run) is easily obtainable for any precision oscillator. It is a measure of the worst-case error, in parts-per-million (ppm), one can expect from the nominal frequency over a period of time. For most synchronization requirements, the time period is 1 year (as used by ITU-T) or 20 years (as used by Telcordia).

Frequency Stability

The frequency stability (or holdover) is the amount of frequency deviation within a set of operating conditions such as temperature and aging. For most synchronization requirements, the time period is 24 hours.

Frequency Drift Rate

Drift was defined by Bellcore when they broke down the GR-1244-CORE holdover requirement into three (3) major components: Initial offset, Temperature, and Drift. The drift rate is the systematic change in frequency with time due to internal changes in the crystal, while the external environment is constant (temperature, no vibration, etc), and at fixed power supply. Oscillator vendors usually specify this as aging over 24hrs at constant temperature (±3°C or ±5°F). The rate of aging is typically greatest during the first 30 to 60 days, after which time the aging rate decreases.

Oscillator Design Considerations

The behavior of the crystal oscillator has an effect on the accuracy of the PLL and its ability to meet stringent Telcordia and ITU-T requirements. Three (3) types of oscillators can be used with Renesas' Network Synchronization PLLs. The oscillators typically differ in how they maintain their output frequency over a range of ambient temperature.

1. OCXO (oven controlled crystal oscillator)
2. TCXO (temperature compensated crystal oscillator)
3. XO (uncompensated crystal oscillator)

A TCXO is more sensitive to changes in ambient temperature conditions than an OCXO. In the case of a TCXO, electrical temperature compensation seeks to offset the effect of a temperature change on the crystal. The OCXO attempts to maintain a constant temperature environment around the crystal using a heater, to a level that is higher than the maximum rated external ambient temperature (typically 85°C).

This section provides some best practice guidelines on how to obtain the optimum performance for the chosen oscillator. However, it is recommended to consult the manufacturer's data sheet and application notes for further guidelines.

Thermal Considerations

Under steady state conditions, crystal oscillators should perform within their declared specifications. Steady state is reached after a warm-up period for the oscillator under conditions of constant temperature and airflow. When the airflow or ambient temperature changes, the oscillator's internal compensation mechanism, if applicable, kicks in. This compensation shows up as small variations of phase and frequency in the oscillator's output clock.

Regardless if using an OCXO, TCXO or XO, every measure should be taken to mitigate the effects of temperature and air flow on the oscillator. Below are some considerations:

1. Try to place the oscillator where air flow is reduced by obstructions, such as placing the oscillator behind taller components or mechanical parts.
2. Keep the oscillator away from heat sources. Avoid solid copper planes (power, ground) on layers below the oscillator; as more copper increases the heat transfer exchange.
3. A plastic or metal case may be available from the oscillator manufacturer, or can be custom designed, to fit over top of the oscillator to provide a layer of insulation from sudden temperature changes. In general, OCXO devices should not require a cover. It is recommended to validate this solution with the oscillator manufacturer.

Power Considerations

The crystal oscillator's power supply should be filtered in accordance with the oscillator manufacturer's recommended method to filter power supply noise. In the case of an OCXO, local bulk capacitors must be provisioned large enough to handle changes in current due to its internal heating unit turning on and off. The use of a dedicated power supply regulator may be required to handle the warm-up current of the OCXO.

Layout Considerations

The objective is to avoid adding any noise to the clock between the oscillator and PLL input pin. Below are some guidelines when co-locating the oscillator with the PLL.

1. Connect the oscillator directly to the PLL and avoid using a buffer; if a buffer must be used, select a technology that will add as little noise as possible.
2. Minimize the oscillator's output clock signal trace length, as the oscillator output is single ended and thereby vulnerable to crosstalk.
3. Provide an option for a series termination resistor at the oscillator output, in case impedance matching is required to eliminate signal over/undershoot.

Target Standards and Recommended Oscillators

This section categorizes recommended oscillator vendors and parts numbers based on applicable industry standards. This is not meant to be an exhaustive list, but does highlight parts that have proven to be suitable with Renesas' Network Synchronization PLLs in meeting applicable industry standards. A summary of the key oscillator parameters applicable for each target standard is provided, which can be used to find alternative oscillators that may not be listed.

G.812 and G.8266 Type I

- Frequency Accuracy: NA
- Frequency Stability (24 hours): ±2ppb
- Frequency Drift Rate (constant temperature): $\pm 2.3 \times 10^{-15}$/s (±0.2ppb per day)

Table 1. Recommended XOs for G.812 and G.8266 Type I

Crystal Oscillator Vendor	Part Order Number (Family)	Type	Frequency	Temperature Range	Notes
NOTE: All oscillators listed in Table 2 are also suitable.					
Rakon (www.rakon.com)	STP3589LF (ROX2522S3)	OCXO	10.000MHz	-40°C to +85°C	1
	STP3586LF (ROD2522S2)	GPSDO-OCXO	10.000MHz	-40°C to +85°C	1,2

1. Tested in the lab by Renesas.
2. GNSS/PTP Disciplined OCXO (via 1PPS input).

GR-1244-CORE and GR-253-CORE Stratum 2 / G.812 and G.8266 Type II

- Frequency Accuracy (20 years [2]): ±0.016ppm
- Frequency Stability (24 hours): ±0.1ppb
- Frequency Drift Rate (constant temperature): $\pm 1.16 \times 10^{-15}$/s (±0.1ppb per day)

For applications that need to meet Stratum 2 holdover requirements per GR-1244-CORE with Renesas' Timing Card PLLs, the below oscillators meet the key oscillator parameters.

Table 2. Recommended XOs for Stratum 2 and G.812 and G.8266 Type II

Crystal Oscillator Vendor	Part Order Number (Family)	Type	Frequency	Temperature Range	Notes
Dapu (www.dptel.com)	O55A-AI01-10.00MHz (O55A)	OCXO (5V)	10.000MHz	-40°C to +85°C	1,3

1. Tested in the lab by Renesas.
2. Per GR-1244-CORE; G.812 specifies 1 year.
3. Frequency Accuracy per G.812.

GR-1244-CORE and GR-253-CORE Stratum 3E / G.812 and G.8266 Type III

- Frequency Accuracy (20 years [2]): ±4.6ppm
- Frequency Stability (24 hours): ±10ppb
- Frequency Drift Rate (constant temperature): $\pm 1.16 \times 10^{-14}$/s (±1ppb per day)

For applications that need to meet Stratum 3E holdover requirements per GR-1244-CORE with Renesas' Timing PLLs, the below oscillators meet the key oscillator parameters. These oscillators may also be used in applications looking for better short term holdover (frequency stability) or aging; for example, an IEEE 1588-2008 application using the PLL as a DCO.

Table 3. Recommended XOs for Stratum 3E and G.812 and G.8266 Type III

Crystal Oscillator Vendor	Part Order Number (Family)	Type	Frequency	Temperature Range	Notes
NOTE: All oscillators listed in the previous table are also suitable.					
CTS (www.ctscorp.com)	1190200-004 (Model 119)	OCXO	12.800MHz	-40°C to +85°C	1
	1380200-004 (Model 138)	OCXO	12.800MHz	-40°C to +85°C	1
Fox (www.foxonline.com)	845-12.8-1	OCXO	12.800MHz	-40°C to +85°C	-
Kyocera (www.kyocera.com)	OO12.8000000M15015AT (OCXO-189A)	OCXO	12.800MHz	-40°C to +85°C	1
MtronPTI (www.mtronpti.com)	XO5184-011sV (XO5184-1588)	OCXO	12.800MHz	-40°C to +85°C	1
Rakon (www.rakon.com)	STP2910LF (CFPO-11)	OCXO	12.800MHz	-40°C to +85°C	1
	U8887LF (Mercury+)	OCXO	12.800MHz	-40°C to +85°C	1

1. Tested in the lab by Renesas.
2. Per GR-1244-CORE; G.812 specifies 1 year.

ITU-T G.8263 (PEC-S-F)

- Frequency Accuracy (1 years [2]): ±4.6ppm
- Frequency Stability (24 hours [3]): ±10ppb
- Frequency Drift Rate (constant temperature): $\pm 1.16 \times 10^{-14}$/s (±1ppb per day)

Table 4. Recommended XOs for G.8263

Crystal Oscillator Vendor	Part Order Number (Family)	Type	Frequency	Temperature Range	Notes
NOTE: All oscillators listed in the previous table are also suitable.					
Rakon (www.rakon.com)	M6141LF (Mercury)	miniOCXO	12.800MHz	-40°C to +85°C	1
	U8295LF (Mercury+)	miniOCXO	12.800MHz	-40°C to +85°C	1

1. Tested in the lab by Renesas.
2. Time interval is for further study, but values of 1 month and 1 year have been proposed.
3. Under G.8263 (amendment) appendix IV temperature profile (±20°C excursion at 0.5°C/min).

Improved Frequency Stability for SETS / 1588 and 5G RRU

For SETS or 5G RRU applications that need better frequency stability over environmental conditions (i.e. temperature) with Renesas' Timing PLLs, the below oscillators may be used. These oscillators may also be used in applications looking for improved short term frequency stability or aging; for example, an IEEE 1588-2008 application using the PLL as a DCO (where the ITU-T G.8263 [optional] holdover requirements are not needed).

Table 5. Recommended XOs for Improved Frequency Stability

Crystal Oscillator Vendor	Part Order Number (Family)	Type	Frequency	Temperature Range	Notes
NOTE: All oscillators listed in the previous table are also suitable.					
Kyocera (www.kyocera.com)	OO12.8000000M14044AT (OCXO-1409A)	miniOCXO	12.800MHz	-40°C to +85°C	1,2
CTS (www.ctscorp.com)	1198004 (Model 119)	OCXO	48.000MHz	-40°C to +85°C	1
Rakon (www.rakon.com)	U7842LF (Mercury+)	miniOCXO	48.000MHz	-40°C to +85°C	1,3
	M5626LF (Mercury)	miniOCXO	12.800MHz	-40°C to +85°C	1,4
TXC (www.txccorp.com)	OG48070001 (OG48)	miniOCXO	48.000MHz	-40°C to +85°C	1

1. Tested in the lab by Renesas.
2. Frequency Accuracy: ±1ppm/1yr; Frequency Stability: ±50ppb/24hr; Frequency Drift Rate: ±5ppb/day.
3. Frequency Accuracy: ±1ppm/1yr; Frequency Stability: ±20ppb/24hr; Frequency Drift Rate: ±1ppb/day.
4. Frequency Accuracy: ±4.6ppm/1yr; Frequency Stability: ±25ppb/24hr; Frequency Drift Rate: ±10ppb/day.

G.8262.1 Enhanced Synchronous Ethernet/OTN Equipment Clock

- Frequency Accuracy (1 year): ±4.6ppm
- Frequency Stability (24 hours): ±0.3ppm
- Frequency Drift Rate (constant temperature): $\pm 1.16 \times 10^{-13}$/s (±10ppb per day)

Table 6. Recommended XOs for eEEC/eOEC

Crystal Oscillator Vendor	Part Order Number (Family)	Type	Frequency	Temperature Range	Notes
NOTE: All oscillators listed in the previous table are also suitable.					
CTS (www.ctscorp.com)	1500002 (Model 150)	miniOCXO	12.800MHz	-40°C to +85°C	1, 2
Rakon (www.rakon.com)	E6241LF (Pluto+)	TCXO	12.800MHz	-40°C to +85°C	1

1. Tested in the lab by Renesas.
2. Frequency Stability: $250ppb_{p-p}$/24hr.

GR-1244-CORE and GR-253-CORE Stratum 3 / G.812 Type IV / G.8262 Option 2

- Frequency Accuracy (20 years [3]): ±4.6ppm
- Frequency Stability (24 hours): ±0.3ppm [4]
- Frequency Drift Rate (constant temperature): $\pm 4.63 \times 10^{-13}$/s (±40ppb per day)

Table 7. Recommended XOs for Stratum 3, G.812 Type IV and G.8262 Option 2

Crystal Oscillator Vendor	Part Order Number (Family)	Type	Frequency	Temperature Range	Notes
NOTE: All oscillators listed in the previous table are also suitable.					
Connor-Winfield (www.conwin.com)	T602-012.8M (T60x)	TCXO	12.800MHz	-40°C to +85°C	1
	DV75C-012.8M (DV75C)	TCXO	12.800MHz	-40°C to +85°C	-
CTS (www.ctscorp.com)	579L128ITT (Model 579)	TCXO	12.800MHz	-40°C to +85°C	1
Epson (global.epson.com)	TG-5500CA-08N 12.8000MB (TG-5500CA)	TCXO	12.800MHz	-40°C to +85°C	1
Fox (www.foxonline.com)	822AR-12.8-2	TCXO	12.800MHz	-40°C to +85°C	1
Kyocera (www.kyocera.com)	KT7050B12800KAW33TAD (KT7050)	TCXO	12.800MHz	-40°C to +85°C	1
	KT5032F12800KAW33TAA (KT5032)	TCXO	12.800MHz	-40°C to +85°C	1
MtronPTI (www.mtronpti.com)	M6161S002 (M616x)	TCXO	12.800MHz	-40°C to +85°C	-
Rakon (www.rakon.com)	509237 (RTX5032A)	TCXO	12.800MHz	-40°C to +85°C	1,2
	508978 (RTX7050A)	TCXO	12.800MHz	-40°C to +85°C	3
	E5624LF (Pluto)	TCXO	12.800MHz	-40°C to +85°C	1
TXC (www.txccorp.com)	7N48071001 (7N48)	TCXO	48.000MHz	-40°C to +85°C	-

1. Tested in the lab by Renesas.
2. The RTX-A is recommended over Pluto due to its lower phase noise.
3. Per GR-1244-CORE; G.812 and G.8262 specifies 1 year.
4. Most XO vendors target ±0.28ppm due to an original requirement in GR-1244-CORE.

G.813 Option 1 / G.8262 Option 1

- Frequency Accuracy (1 year [1]): ±4.6ppm
- Frequency Stability (24 hours): ±2ppm
- Frequency Drift Rate (constant temperature): $\pm 1.16 \times 10^{-13}$/s (±10ppb per day)

Table 8. Recommended XOs for G.813 Option 1 and G.8262 Option 1

Crystal Oscillator Vendor	Part Order Number (Family)	Type	Temperature Range	Notes
NOTE: All oscillators listed in previous table(s) are suitable. However, care must be taken when looking at Frequency Drift Rate (most TCXOs specify ±4.63x10-13/s (±40ppb/day)).				

1. Time interval is for further study, but values of 1 month and 1 year have been proposed.

GR-253-CORE SONET Minimum Clock / G.813 Option 2 / Line Card

- Frequency Accuracy (20 years [1]): ±20ppm
- Frequency Stability (24 hours): ±4.1ppm
- Frequency Drift Rate (constant temperature): $\pm 5.8 \times 10^{-12}$/s (±0.5ppm per day)[2]

Table 9. Recommended XOs for SMC, G.813 Option 2 and Line Card

Crystal Oscillator Vendor	Part Order Number (Family)	Type	Temperature Range	Notes
NOTE: All oscillators listed in previous table(s) are suitable.				
MtronPTI (www.mtronpti.com)	M6111S059 (M611x)	TCXO	-40°C to +85°C	-

1. Per GR-1244-CORE; G.813 does not specify a time period.
2. Per GR-253-CORE.

GR-1244-CORE STRATUM 4 and 4E / Line Card

- Frequency Accuracy (20 years): ±32ppm

Table 10. Recommended XOs for Stratum 4/4E and Line Card

Crystal Oscillator Vendor	Part Order Number (Family)	Type	Temperature Range	Notes
NOTE: All oscillators listed in previous table(s) are suitable.				
Fox (www.foxonline.com)	826A-12.8-1	XO	-40°C to +85°C	
MtronPTI (www.mtronpti.com)	M2532S104 (M2532)	XO	-40°C to +85°C	

Revision History

Revision Date	Description of Change
April 21, 2023	▪ Updated hyperlinks to Renesas website in Introduction. ▪ Added new Rakon part to Table 1 and Table 4. ▪ Changed Rakon part to U8887LF from U6858LF in Table 3. ▪ Added new CTS and TXC parts to Table 5. ▪ Added new TXC part to Table 7.
September 9, 2020	▪ Updating to Renesas template and replacing occurrences of IDT. ▪ Added new sections for G.812 Type I and Type II. ▪ Added Rakon U6875LF to Stratum 3E table. ▪ Added Rakon U7842LF to Improved Frequency Stability table (recommended for 5G RRU applications). ▪ Added new section G.8262.1 (moved some XOs from Improved Frequency Stability to this new section).
October 27, 2016	Remove references to IDT crystal and replace with FOX.
April 29, 2016	Add new section “Improved Frequency Stability for SETS / 1588" and the recommended crystal vendors lists.
October 20, 2015	▪ Added CTS and Kyocera vendor information to table 1. ▪ Added CTS vendor information to table 3.
June 1, 2015	Added Epson and Kyocera TCXOs to table 3.
September 10, 2014	▪ Added new section, “ITU-T G.8263 (PEC-S-F)” ▪ Added Synchronous Equipment Timing Source (SETS) verbiage throughout various sections of app note. ▪ Updated title to include SETS information. ▪ Updated “Target Standards and Recommended Oscillators” section.
December 4, 2013	Initial release. ▪ Re-created from existing released document that had no “AN” number. ▪ Converted to new template and assigned an “AN” number.

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