

Rakon's Miniature High-End Space Grade OCXO

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INTRODUCTION

Space demand is converging along the general trend already observed in the Telecom market; this has led to:

- miniaturization,
- usage of smaller components,
- ensuring the highest levels achieved for key performance attributes;
- looking for lower cost solutions,
- reduced delivery lead-times.

This evolution has required us to define, design and qualify new structures and solutions for both quartz crystal resonator and OCXO thermal structures, while still keeping an industrial approach in relation to process controls, reproducibility of final performance and competitive costs.

This fact sheet presents actual achievements and further feasible performances, based on our newest version of Rakon's Miniature Space Grade OCXO.

QUARTZ CRYSTAL RESONATOR

For many years Rakon has been at the forefront of space technology, developing and qualifying the highest performance Space "QAS" structure for our crystal resonators, with encapsulation in the HC40CW (T-2108) package.

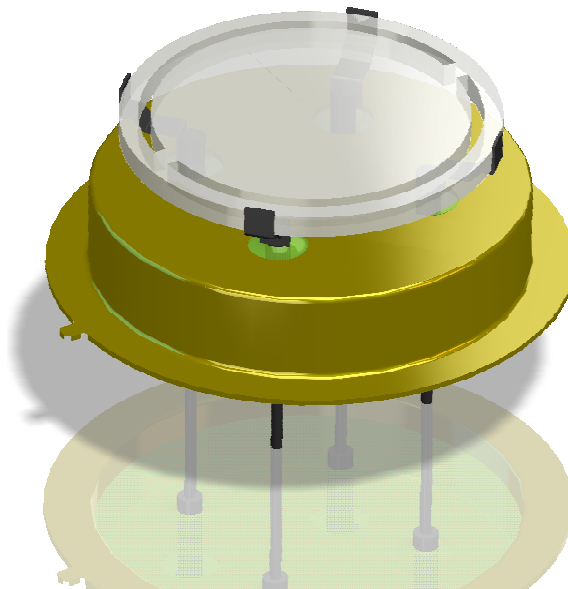


Figure 1: HC40CW "QAS" resonator

Today this package of crystal resonator has been refined and is commonly used in all our Space USOs (Ultra Stable Oscillators) allowing Rakon to reach the highest stability levels achievable.

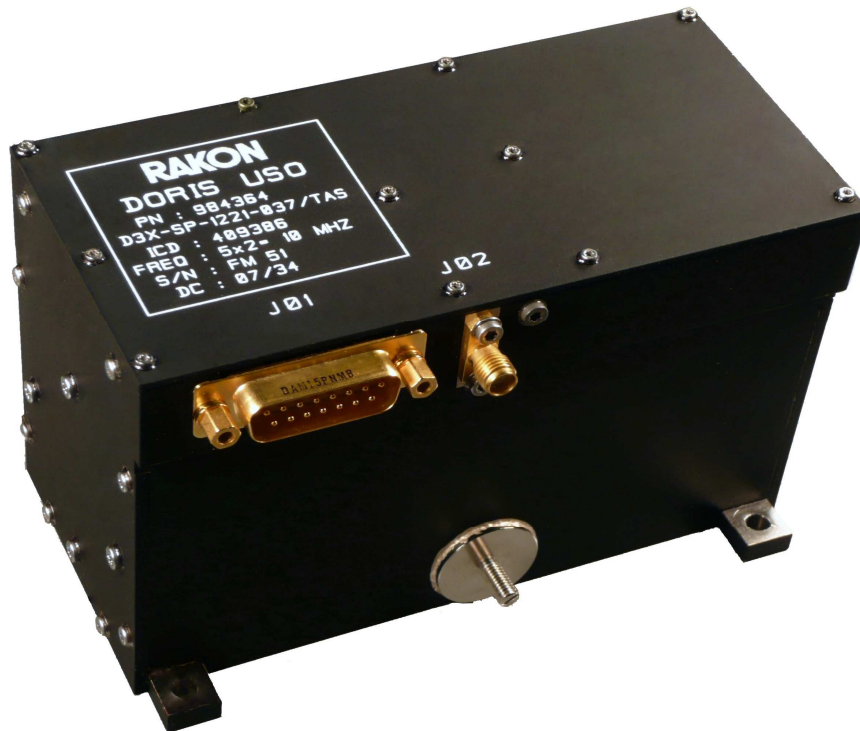


Figure2: RAKON Space Flight Model USO

For the last 10 years, the team at Rakon France has permanently improved overall performances of the USO and related "QAS" crystal resonator, through challenges and support by the French Space Agency (CNES), to continuously improve physical limits.

Rakon's latest Flight Models series of USOs are once again "State of the Art" for space applications, in terms of key performances, indicators:

- Thermal sensitivity within $5\text{E-}14/^{\circ}\text{C}$ [1]
- Short term stability better than $6\text{E-}14$ from 1s to 10s [2][3]

These performances have been measured during thermal vacuum tests, simulating actual operating conditions of the satellite in space.



Figure 3: Rakon's USO is integrated into Cryosat-2 satellite (launch on 2010 April 8th)

HIGH-END SPACE GRADE OCXO

The first miniaturized version of the high-stability space OCXO was designed and qualified in the frame of QZSS (for Quasi-Zenith-Satellites System - JAXA), then deployed for the “Mars Detector” (for the Chinese Academy of Science).



Figure 4 : Rakon's High-End Space Grade OCXO



Figure 5 : QZSS constellation

The first of the 3 satellites (nickname “Michibiki”) will be launched in Japan’s fiscal year 2010. The first launch of satellites for the “Mars Detector” is scheduled for October 2010.

Rakon’s High-End Space OCXOs offer a good trade-off between stability levels and size / mass:

- Frequency stability $< 1\text{E-}7$ all causes for 15 years
- Short term $\sim 5\text{E-}13$ from 1s to 10s
- Temperature sensitivity better than $5.0\text{E-}12/^{\circ}\text{C}$
- Volume of 0.2 litre & mass of 200g max.

MINIATURE HIGH END SPACE GRADE OCXO

Recently miniaturization has been successfully completed and qualified, thanks to the downsizing of our “QAS” design structure for quartz crystal resonators, with sealing in the HC37CW low profile package.



Figure 6: HC37CW QAS crystal resonator

This new high performance “QAS” resonator is now commonly used in our new Miniature High-End Space Grade OCXO and in airborne and military applications. Currently an industrialized version is underway to address the very high-end OCXO demand in the telecom market (infrastructure) where frequency accuracy is required for a long operating lifetime.

Presented below are key performance attributes relating to “QAS” crystal @ 10MHz into HC37CW:

Parameter	Typical Value
Ageing	2.E-11/day after 1 month
Acceleration sensitivity	3.0.E-10/g Vector
Magnetic field sensitivity	1.E-13/Gauss
Frequency Recovery	~2 hours after 1 month Off
Frequency retrace	1.E-10

Table 1: key performances of “QAS” @ 10MHz

g Sensitivity (E-10) QAS @ 10.0MHz into HC37CW	Ox	Oy	Oz	Gamma
Mean	1.2	1.7	1.5	2.9
Standard Deviation	0.6	0.9	0.9	1.0

g Sensitivity - Gamma Vector (E-10) QAS @ 10.0MHz into HC37CW					
Performance	< 1.7	< 2.5	< 3.0	< 3.5	< 5.0
Percentage	15%	40%	57%	76%	100%

Table 2: QAS @ 10.0 MHz / g Sensitivity Data

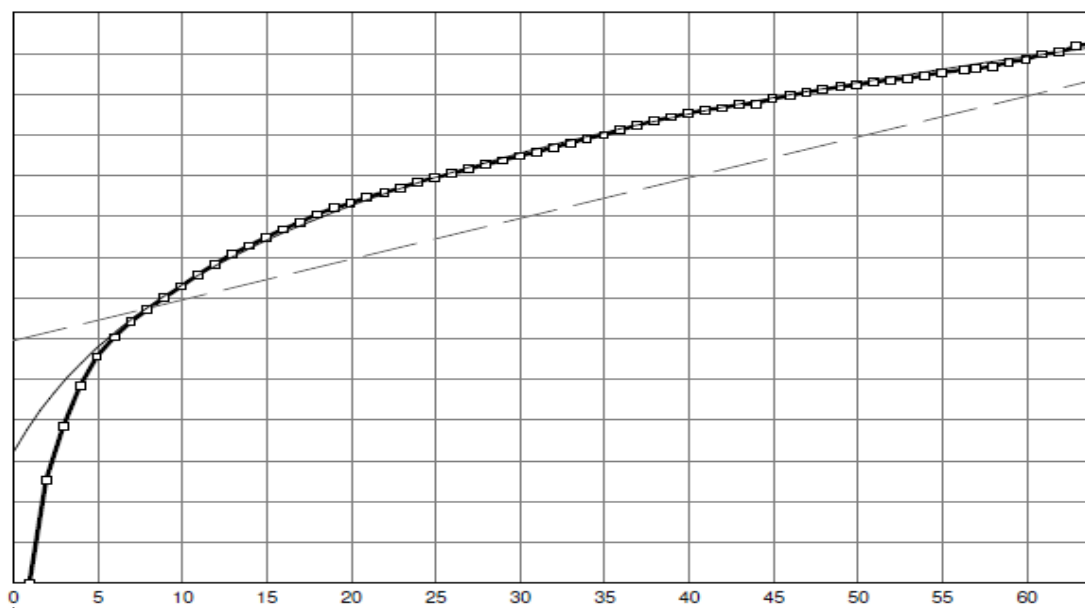


Figure 7: early ageing @ 10.0MHz (typical)

(Vertical: 1E-9/division - Horizontal: 5 days / division - Specification 3E-9 / month)

After early ageing (complete stabilization process before shipment from the factory), this kind of crystal resonator allows faster frequency recovery compared to standard crystal resonator structures (see figure 8 below). This means that after a couple of hours after being powered on, the frequency of crystal returns to its stabilised value, similar to the final frequency achieved after the complete initial stabilization (duration to be compared to a few days of continuous operation with standard crystal structures).

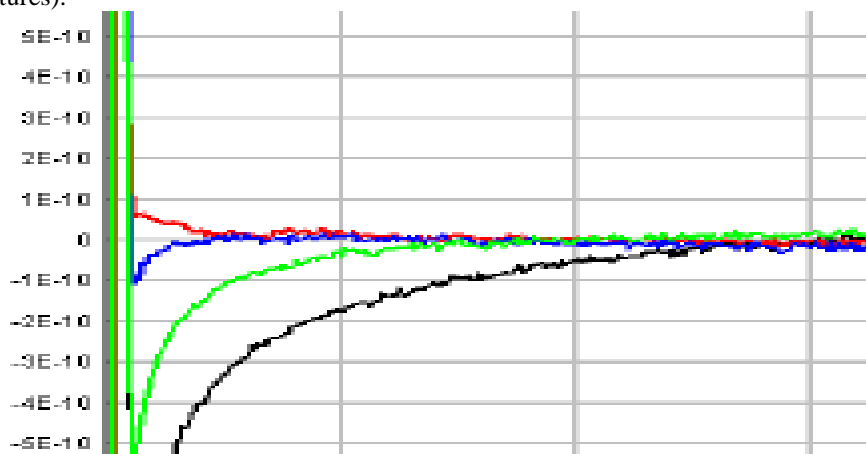


Figure 8: QAS - Frequency recovery after 1 month storage
(Vertical: 1E-10/division – Horizontal: 2h/division)

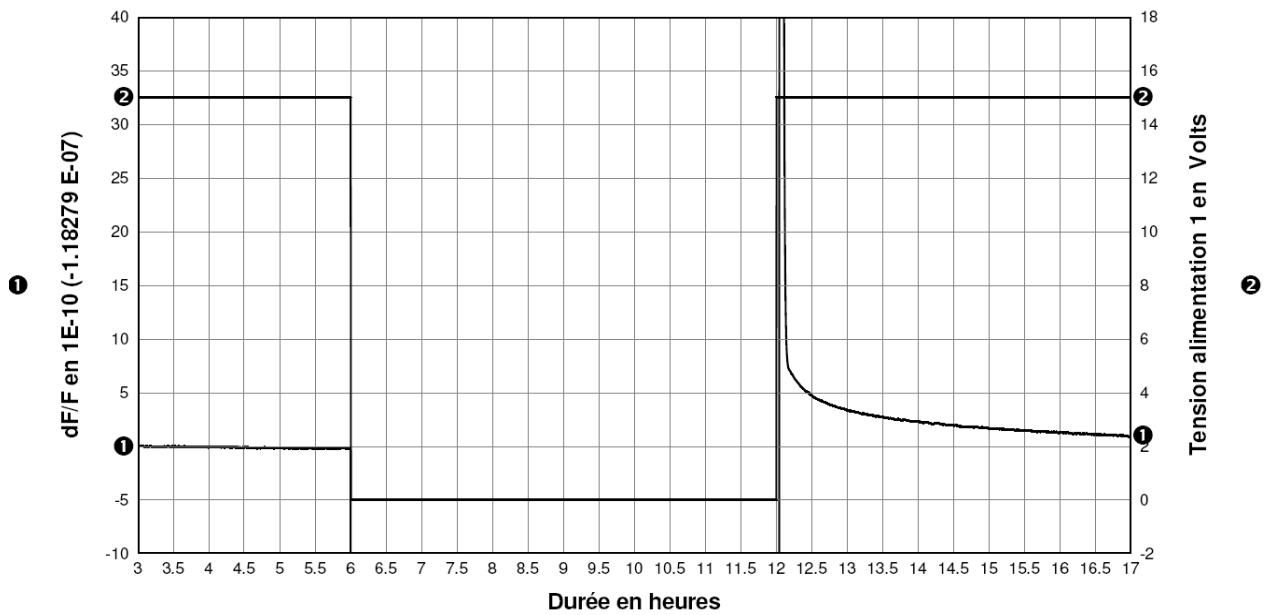


Figure 10: QAS – Typical Retrace effect
(Vertical: 5E-10/division – Horizontal: 0.5h/division)

THERMAL DESIGN AND STRUCTURE



Figure 11: Miniature High End Space Grade OCXO

The thermal design is qualified under the following environmental conditions:

- Operating from -40°C to +85°C
- Steady state power < 2.0W under vacuum

That thermal design allows reaching high stability with sensitivity better than 5E-12°C

Mechanical qualification:

- 27grms random vibration (up to 2kHz)
- 900g half sine shocks / 0.5ms
- 1200g half-sine shocks / 0.3ms (survival)

Mass ~85g typical

Volume: 60cm³

This product is now fully qualified and flight Models have been delivered to end customers.

MAIN PERFORMANCES OF THIS NEW MINIATURE HIGH END SPACE GRADE OCXO

- Frequency stability better than 200ppb including all causes (ageing, radiations, ...) over 15 years life time
- Thermal sensitivity better than $1\text{E-}11/^{\circ}\text{C}$
- Acceleration sensitivity better than $5\text{E-}10$ per g vector
- Low frequency retrace (E-10 range)
- Fast frequency recovery (hours instead of days for devices to re-stabilize after 1 month off)

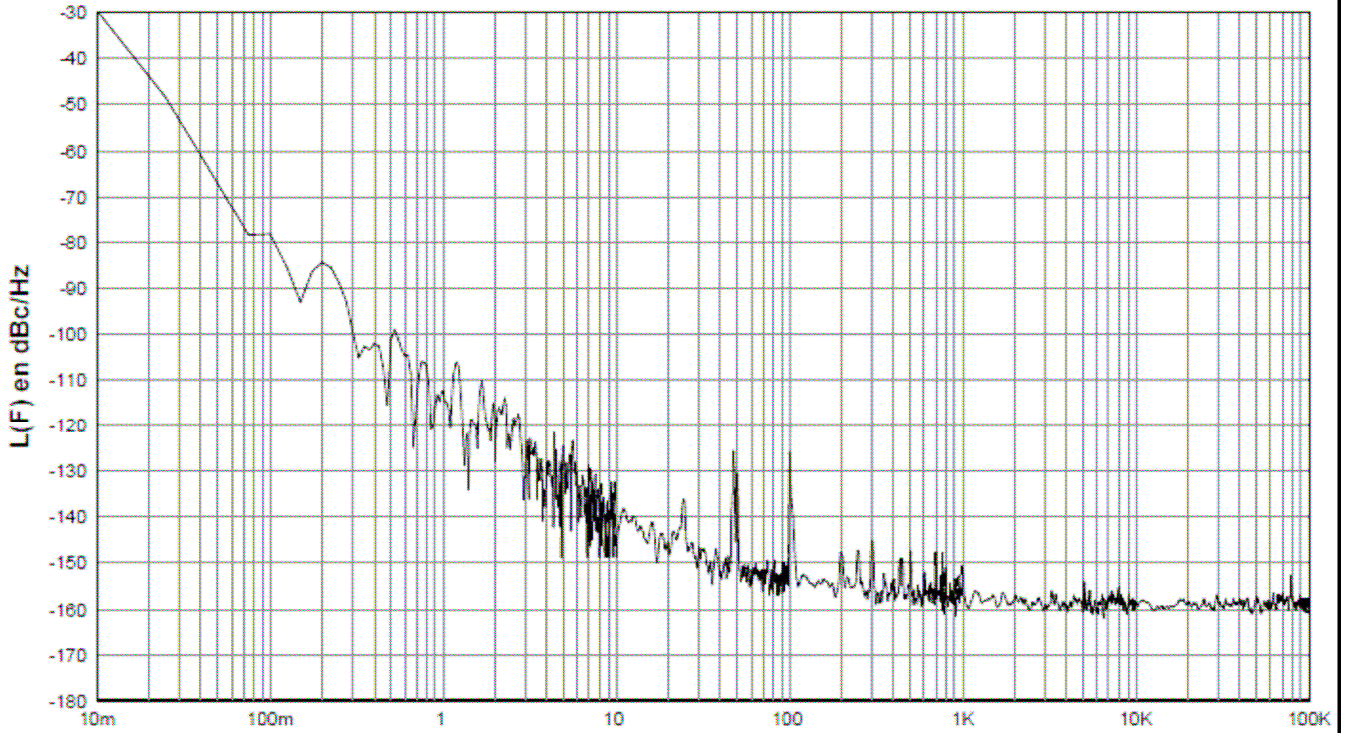


Figure 12: Phase Noise

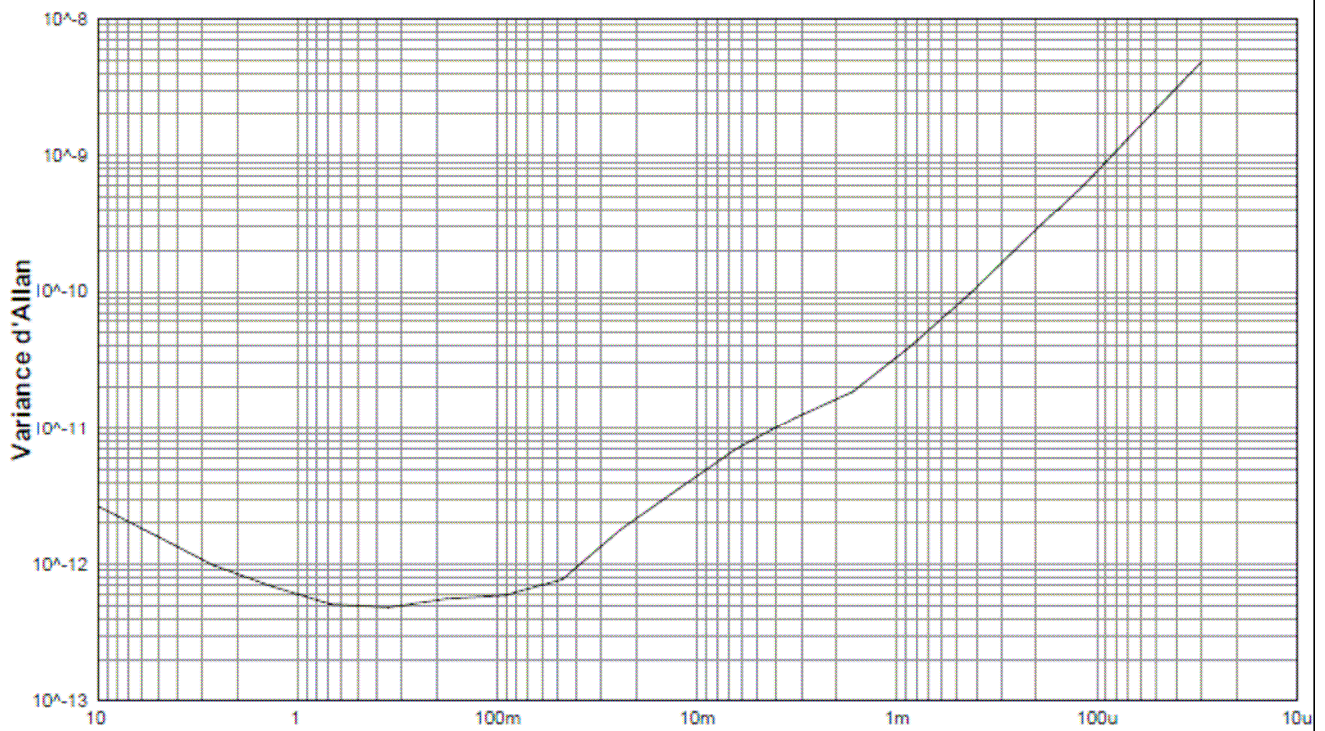


Figure 13: Short term Stability (ALLAN)

CONCLUSION

Rakon has more than 30 years of experience in the space domain (our crystal resonators have been ESCC qualified since 1979) and offers a complete range of solutions, from the highest-end, most demanding OCXO applications (such as DORIS) down to more standard solutions (such as down to 2ppm for 20 years lifetime all causes).

The miniature high-end design has already been adapted to higher frequencies (up to 50MHz output).

New developments are now available to fulfill OCXO customer requirements and which offer the following:

- Higher frequency ranges (up to above 100MHz - Rakon is ESCC qualified up to 140MHz),
- More compact size (volume < 30cm³) and lighter packages (mass < 50g),
- Shorter lead-times for delivery of Flight Model units (target of 30-32 weeks max. ARO).

REFERENCES

- [1] L. Schneller, P. Canzian, V. Candelier, S. Galliou, G. Cibiel "New state of the art of thermal sensitivity with Space Ultra Stable Quartz Crystal Oscillator", EFTF 2010
- [2] J Lamboley, V Candelier, F Courtade, "Ultra-stable 5 MHz Xtal resonator with very low G-sensitivity and noise", *18th EFTF pp 359-364, 2004*
- [3] Vincent Candelier, Patrice Canzian, Jacques Lamboley, Michel Brunet, Giorgio Santarelli – *Space Qualified 5 MHz Ultra Stable Oscillators* - IEEE EFTF Frequency Symposium Proceedings 2003