# Low Noise Master Oscillator
# LNMO

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## OBJECTIVE AND STUDY PLAN

### Objective

The objective of this study was to design, manufacture and test an Engineering Model of a compact and low cost reference oscillator meeting the requirements specified in Updated Requirements Specifications for Reference Oscillator.

This equipment shall be free of any export licence control for use in European space programs.

### Study plan

We describe here the study plan for the tasks that have leaded to the development of a Low Phase Noise Reference Oscillator. The plan followed closely the SOW and divided the activity in three phases:

- Phase 1 : Review and preliminary design
  - Task 1: Requirements and Technology Review
  - Task 2: Preliminary Design
- Phase 2 : Breadboarding and design
  - Task 3: Building Block Design and breadboarding
  - Task 4: Detailed Design
- Phase 3 : Manufacture, Assembly, Test and Conclusions
  - Task 5: Manufacture and Assembly
  - Task 6: Test
  - Task 7: Overall Assessment and Recommendations

**Phase 1** dedicated to the review of the requirements and current technology as well as the identification of criticalities which has resulted in the definition of a preliminary design. This Phase has been concluded by a Preliminary Design Review.

**Phase 2** dedicated to the detailed design of the oscillator, including the development and validation (at breadboard level) of the identified critical building blocks. This Phase has been concluded by a Detail Design Review.

**Phase 3** dedicated to the manufacture, assembly, test of 6 Low Noise Reference Oscillators, as well as the definition of plans and recommendations for qualification. This Phase has been concluded by the Final Review.

**PHASE 1**

**Task1: Requirements and Technology Review**

Competitor state of the art
After some space OCXO manufacturer data sheets analysis (TEMEX, RAKON (publication), SYMETRICOM, WENZEL, FEI (publication), ASTRIUM), none warranty at 100% ESA requirements.

Customers needs
All identified customer needs at 10MHz are covered by the Low Noise Reference Oscillator but only a few demands request this level of specification, target price is depending on OCXO performances and quantity.
Reference Oscillator Technology Assessment

The low noise reference oscillator will be a crystal oscillator built with in mixed technologies (PCB+SMD parts+ encapsulated macro functions) using a simple oven regulation and an oven size reduce to its minimum in order to gain in term of size, weight , consumption and cost.

Risk and cost assessment

| Design | Risk | Actual cost | Possible gain | cost 60units/year |
|---|---|---|---|---|
| New design | -phase noise at 10Hz<br>- frequency stability vs temperature range | 0.72 | change crystal source<br>and with use of commercial parts | 0.67<br>0.28 |

Cost normalized to current Spectratime OCXO design

**Task 2: Preliminary Design**

**Breadboard Preliminary Design**

**Metrologic electronic solutions**
In order to reach the contract specification several schemes have been tested on a preliminary breadboard. Design was essentially based on tests performed on two types of oscillators and three types of buffers. All the schemes have been preselected thanks to the large experience of Spectratime experts. The priority was to reach the phase noise specification, by selecting schemes and crystals.

- Oscillator
  - Colpitts oscillator buffered by a common emitter stage
  - Cascode Colpitts oscillator buffered by a common base stage
  - Colpitts oscillator with frequency output performed at crystal level buffered by a common base stage
  - SPECTRATIME current solution: cascode Butler oscillator with ACG
  - Simplified SPECTRATIME solution: Butler oscillator with ACG
  - Cascode Butler oscillator with frequency output performed at crystal level buffered by a common base stage without ACG
- Buffer
  - Common base output power amplifier
  - Cascode output power amplifier
  - Push-pull output power amplifier
- Voltage regulation: the current Spectratime voltage regulation has been used with an improvement of its filtering.
- Oven loop: a single oven with a proportional loop.

**EEE parts pre-selection**

- Signal transistors:2N2222A,2N2907A,2N2369A,2N4416,2N2857,BFR92
- Power transistors:BDS20 or equivalent
- Varactor : DH76150 and DH71330
- Schottky diode:1N5819UR-1
- SC cut Crystals: 5MHz and 10MHz in HC40 or HC37 holder from: Bliley, NEL and KVG

## LNMO Preliminary Design

### Global block diagram

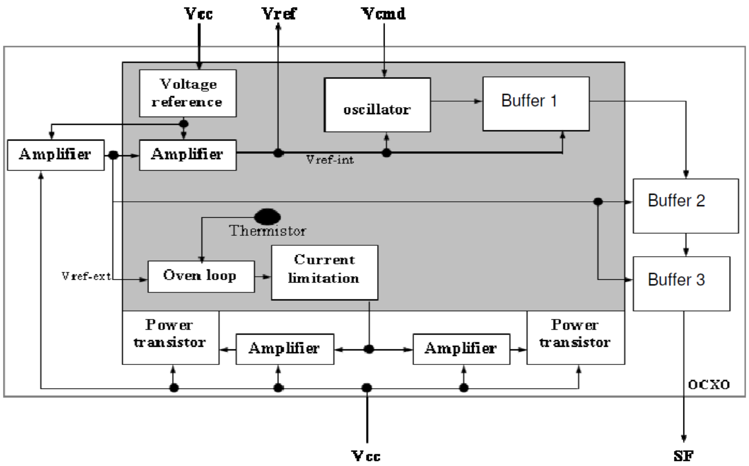



Fig. 2

In the gray area of the block diagram are all the thermal sensitive functions which will be implanted on the heated board. A thermal simulation of this board has to be performed taking into account all components sensitivities in order to place each of it in a compatible area.

### Thermo mechanical structure

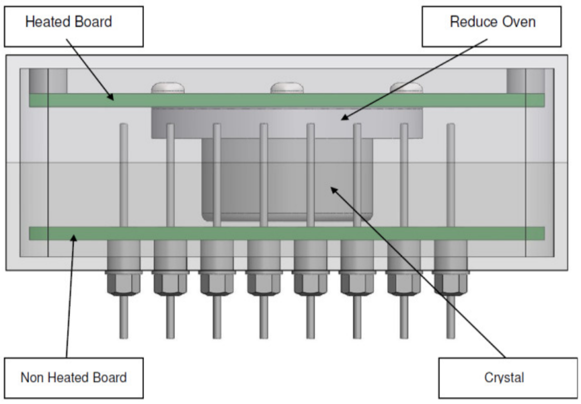



Fig. 3 Package size target: 50x50x30 mm

A thermo-mechanical analysis has been performed in order to identify all the structure resonance and thermal behavior:

- first resonance was found at 825Hz and has been increased up to 1250Hz by increase of the PCB thickness (1.6mm to 2.4mm)

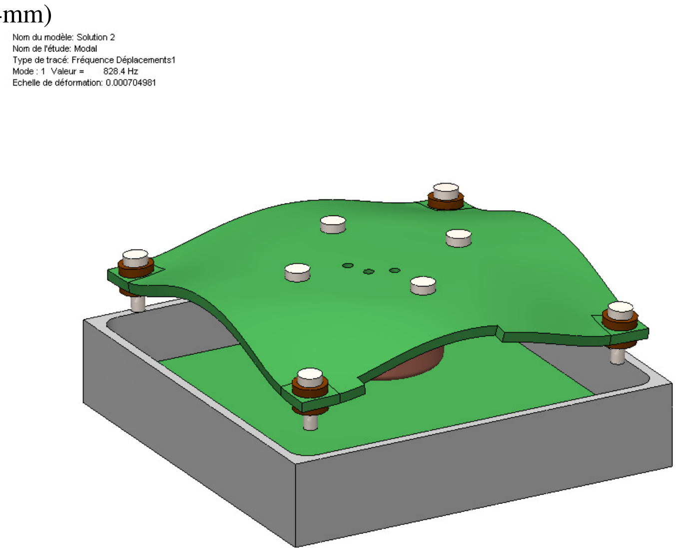



Fig.4 Mode shape, 1st frequency (828.4 Hz), PCB bending, Z direction

- a large area at heated board level has been identified with a thermal gradient compatible with required frequency stability (<0.4°C at PCB level and 0.05°C at crystal level) .

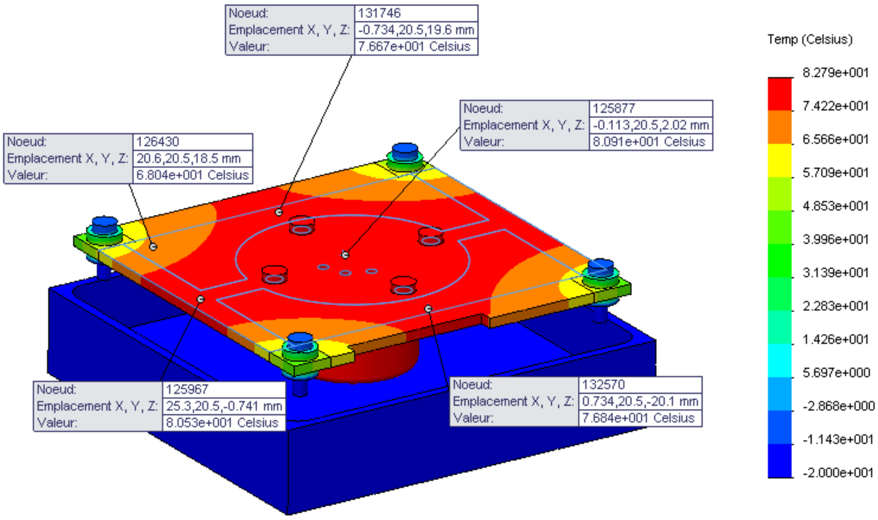



Fig. 5 Temperature plot, cold case, upper PCB (°C)

**Critical Building Blocks Identification**

Four blocks are critical:

- Oven, found a compromise between size (consumption) and temperature regulation (frequency stability, phase noise at f ≤ 1Hz)
- Output amplifier (level and phase noise)
- Oscillator and Crystal (aging, phase noise and frequency stability)
- Filtering (phase noise, spurious).

**Updated Requirements**

Some parameters have been updated or added:

- Update: output power, spurious, phase noise, supply voltage, power consumption, warm up duration, random vibration and shock levels,
- Added: sine vibration, warm up power, start up time, retrace, magnetic field sensitivity

**Preliminary test plan**

Tests will be performed on 6 EM:

- initial tests on 6 units
- vibration and shocks on 2 units
- radiation tests on 4 units
- final tests on 6 units

**PHASE 2: BREADBOARDING AND DESIGN**

**Task 3: Breadboard design**

This preliminary design has been performed in order to test all the preselected solutions and has been mounted in a standard rubidium commercial package. All functions have been implemented on a dedicated PCB with several possibilities of configuration.

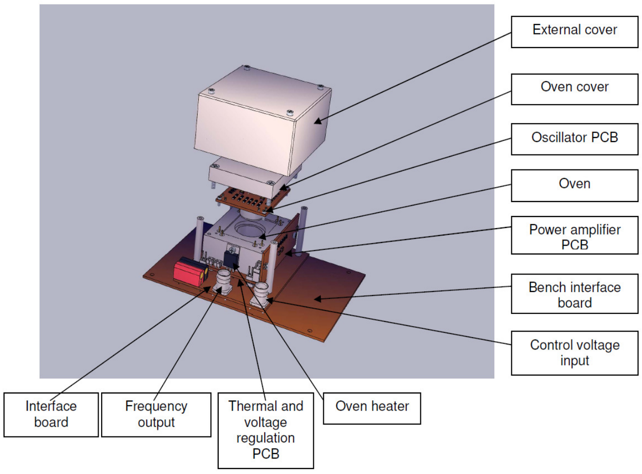



Fig. 1 breadboard design

## Breadboards Tests Results

Only some measurements are representative to the final design: phase noise, output level, harmonics, and frequency stability versus load
The others parameters are linked to the thermo- mechanical design and will be measured on the EM.
Oscillator choice

During initial tests two configurations have given results close to the target:

- Colpitts with output at crystal level , buffered by a common base stage
- Butler single transistor with ACG , buffered by a common collector stage
- As cost reduction is one of the objectives of this study we preferred work on the optimization of the Colpitts solution which uses less actives parts.

Optimization of Colpitts oscillator with frequency output performed at crystal level
Except phase noise all measurable parameters have been reached during bread boarding phase.
All 10MHz crystals have given similar phase noise performances. Final choice will be done after tests on EM.
5 MHz crystals are too sensitive to drive level and after multiplication by 2, the 10MHz phase noise specification can't be reached.

Phase noise has to be improved on EM:

- From 1Hz to 10Hz, it is linked to crystal loaded quality factor
- From 10Hz to 1kHz , it is linked to amplifier transistor flicker noise

**Task 4: Detailed Design**

**Electrical Design**

**Crystal definition**
In order to reach all the LNRO specified performances we have to use an SC cut overtone 3 swept crystal resonator. Two specifications have been issued:10 MHz SCP3 resonator in HC37U and HC40 holder
As we have obtained the same results with all types, we will finalize our choice after EM testing. However, our preference is the crystal in the HC37U holder.

**Oscillator and power amplifier**

After having tested several schemes on the preliminary breadboards we have chosen to use:

- Colpitts oscillator with frequency output performed at crystal level buffered by a common base stage:A2P-Y034A
- Common base output power amplifier:A2P-Y012A

This configuration gives us the best phase noise results.

**Voltage regulation**

For voltage regulation we have chosen a 1N819A zener filtered by a low pass filter and buffered by an operational amplifier and a 2N2222A transistor. With 15V supply voltage the regulated voltage will be 10V and with 12V supply voltage the regulated voltage will be 8V. The voltage regulation will be completed with low pass RC filter at each stage level.

**Oven loop regulation**

For the oven loop we have chosen to use a proportional integer regulation in order to can generate a larger gain in the loop without oscillation and minimize the loop error. With a proportional regulation the gain is limited to 100, otherwise the loop oscillate.

**Components selection**

During bread boarding test some actives components have been tested and selected:

- At oscillator level we can use different transistors: BFR92 or 2N2369A
- At first common base buffer level we can use different transistors:BFR92 or 2N2369A
- At common base power buffer level ( 2 stages) we can use different transistors:BFR92, 2N2369A or 2N2222A
- For voltage regulation buffer we will use a 2N2222A
- For heating power transistor we will use 2 BDS20 in TO257 package
- For oven loop current limitation we will use a 2N2222A
- For the oven loop regulation and the voltage regulation we will use an LM124 or a RH1014 operational amplifier
- For voltage reference we will use a 1N829A
- For supply polarity inversion protection ,we will use a diode 1N5819UR-1
- All these components, except the BDS20, will be in SMD technology
- For passives components we will use capacitors, resistors and inductors in SMD technology.

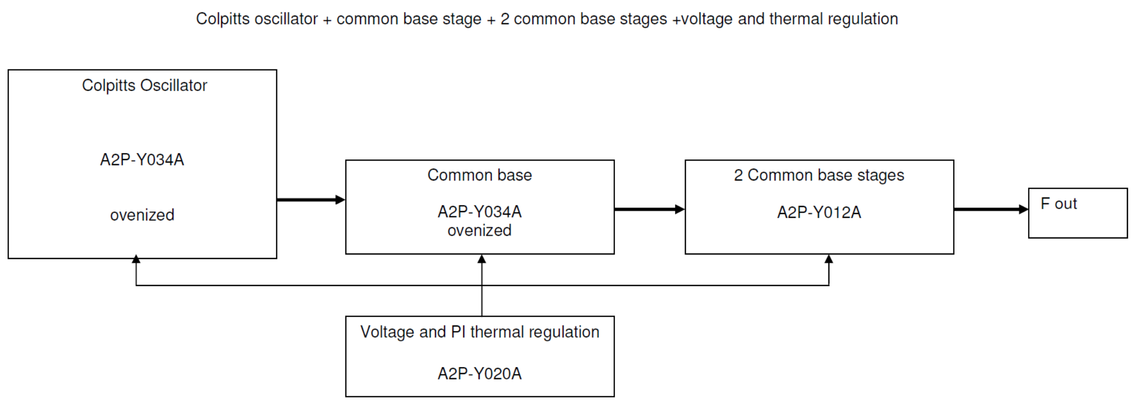



Fig. 6 Electrical block diagram

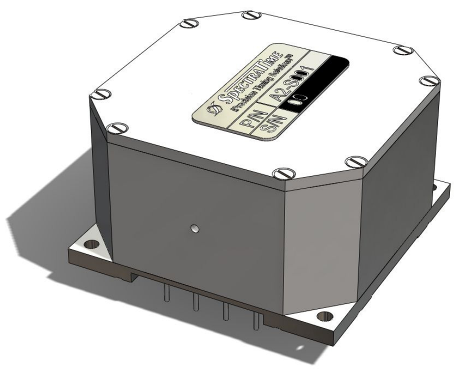


Fig. 7: Mechanical design (50x50x30 mm)

**PHASE 3**

**Task 5: Manufacture and Assembly**
6 EM have been manufactured according to MATV document, LNROA2X:

- 4 dedicated to radiation tests
- 2 dedicated to environmental tests

**Task 6: Tests**

HC37U LNRO design has demonstrated its ability to reach the targeted specification, only HC40 LNRO behaviour versus temperature has to be improved.
All units have successfully passed the qualification tests, no degradation between initial and final tests.

**Radiation test**
This test has been performed at ESTEC. The OCXO has been irradiated with a cobalt 60 source in the following conditions:

- Measurement with TIMEPOD 5330A: RF output level, phase noise and short term stability
- 4 OCXO with a dose rate of 36rad/hour up to 10krad cumulated dose
- Measurement with TIMEPOD 5330A: RF output level, phase noise and short term stability
- 4 OCXO with a dose rate of 360 rad/hour up to 100krad cumulated dose
- Measurement with TIMEPOD 5330A: RF output level,  phase noise and short term stability
- The dose rate is adjusted by the distance from the considered OCXO to the CO-60 beam

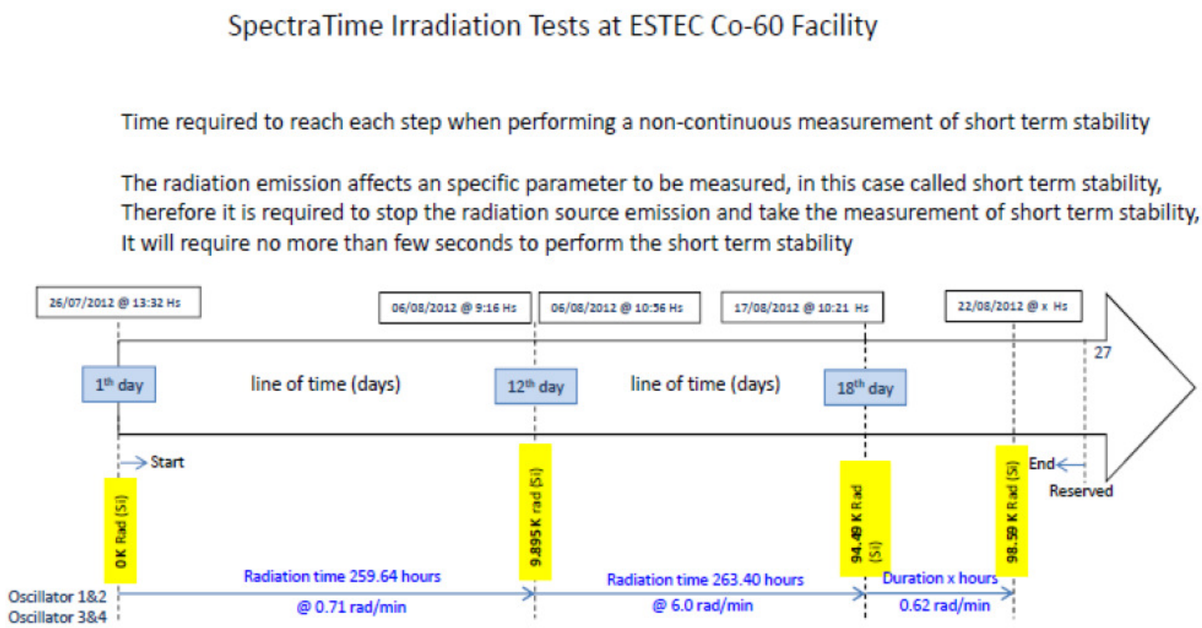



Fig.8

SN02

| **TEST RESULTS** | **Specification** | **initial** | **Final** | **Comments** |
|---|---|---|---|---|
| LNRO Serial Number | | SN02 | SN02 | |
| Crystal type | | HC37<br>KVG | HC37<br>KVG | |
| Active parts type | | indus | indus | |
| Output signal under 50Ω | | | | |
| Output signal level(dBm) | 10+/-1 | 10.2 | 10.2 | |
| Harmonics/sub-harmonics(dBc) | -40 | -50 | -52 | |
| Spurious(dBc) 0.1MHz to 1MHz<br>1MHz to 1GHz | <-120<br><-100 | <-120<br><-108 | <-120<br><-108 | |
| Return loss(dB in-band +/-50kHz ) | 15 | 30 | 30 | |
| Frequency accuracy | 1E-8 | **<1E-8** | **<1E-8** | |
| Frequency adjustment | +/- 2E-7 | **3.25E-7**<br>**1.15E-7** | **4.65E-7**<br>**2.53E-7** | Drift linked to radiation<br>Non swept crystal |
| Frequency stability over life(1) | +/-2E-7 | 1.71E-7 | 1.71E-7 | |
| versus operating temperature range under vacuum | +/-1E-9 | 2E-10 | 4E-10 | Difference linked to aging during initial test |
| aging | +/-1.2E-7 | | | |
| sensitivity to Power supply15V+/- 5% per V | | 1E-11 | 1E-11 | |
| Sensitivity to load (50 ohms +/-10%) | | 6E-11 | 6E-11 | |
| short term stability(1s) | 1E-12 | 7E-13 | 7E-13 | |
| sensitivity to magnetic field per Gauss<br>+/- 2 Gauss | 2E-11 | **1E-10**<br>**Y** | **1E-10**<br>**Y** | Compliant in the other directions |
| SSB phase noise (dBc/Hz) | -110<br>-135<br>-150<br>-160<br>-160<br>-160 | -110<br>-140<br>-154<br>-164<br>-169<br>-170 | -112<br>-143<br>-155<br>-164<br>-167<br>-169 | Improvement linked to crystal stabilization |
| Power consumption(W) -20°C<br>+60°C | 2.5W<br>1W | 1.4<br>0.6 | 1.43<br>0.7 | |
| Power consumption during warm-up at -20°C | 4W | **4.64** | **4.65** | |
| Warm-up time at -20°C | 30min | 7 | 7 | |
| Retrace | +/- 5E-9 | 1.2E-9 | 1E-9 | |
| Start up time at -20°C | 10s | <1s | <1s | |
| Dimensions(cm3) | 75 | 75 | 75 | |
| Mass(g) | 100 | 98 | 98 | |

Note 1: as aging isn't measured on EM we will take worst case condition for calculation, +/-1.2E-7 for aging and +/-5E-8 for radiation.

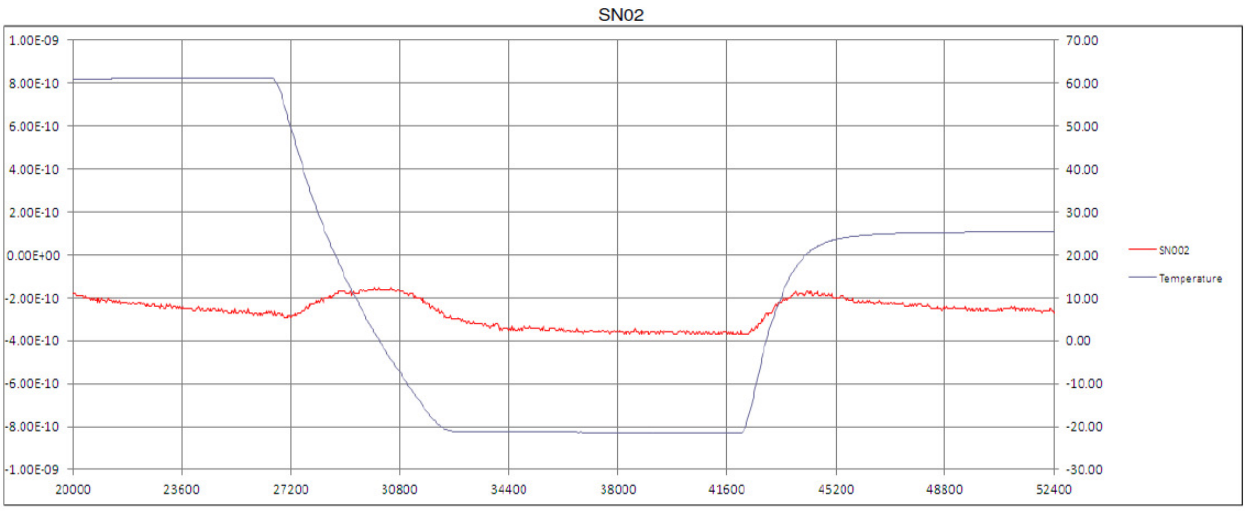
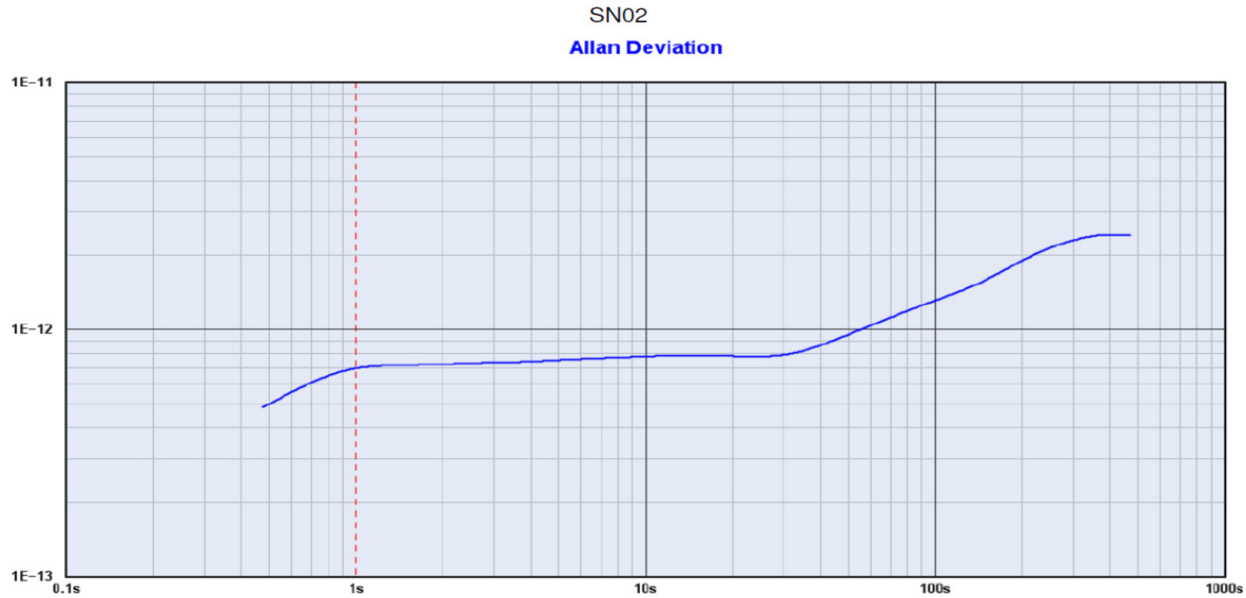


Fig 9: Stability versus temperature




| Trace | Notes | Input Freq | Input Amplitude | Ref Amplitude | Sample Interval | ADEV at 1s | Duration | Acquired |
|---|---|---|---|---|---|---|---|---|
| LNRO SN02 after RVT | | 10.000 MHz | 10 dBm | 12 dBm | 0.473 s | 6.96E-13 | 30m 0s | 3801 pts |

Fig. 10  Short term stability

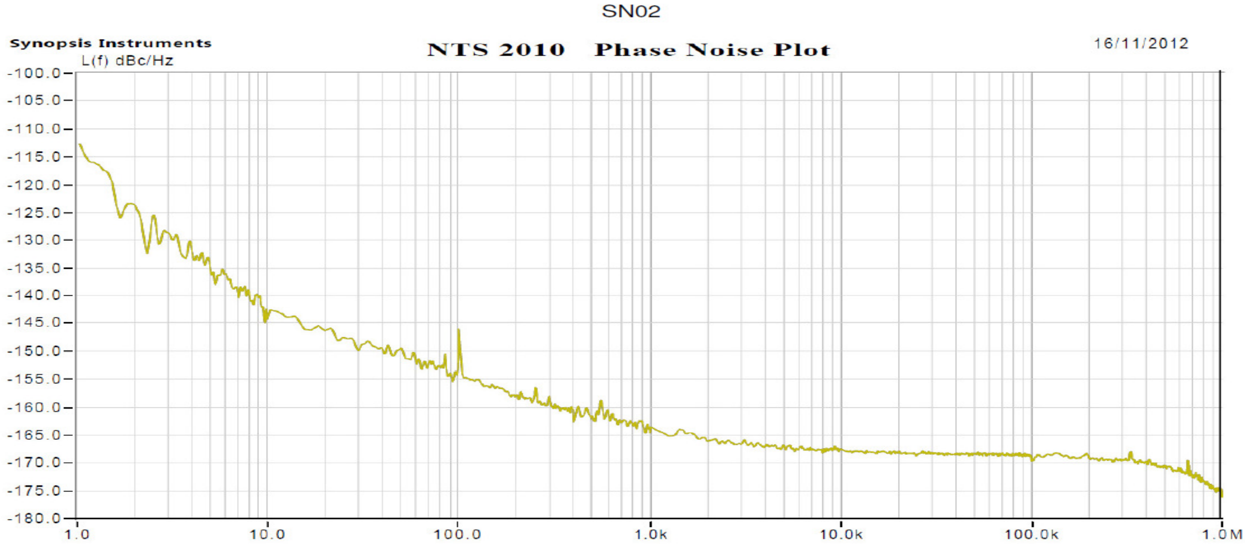



Fig. 11: Phase noise

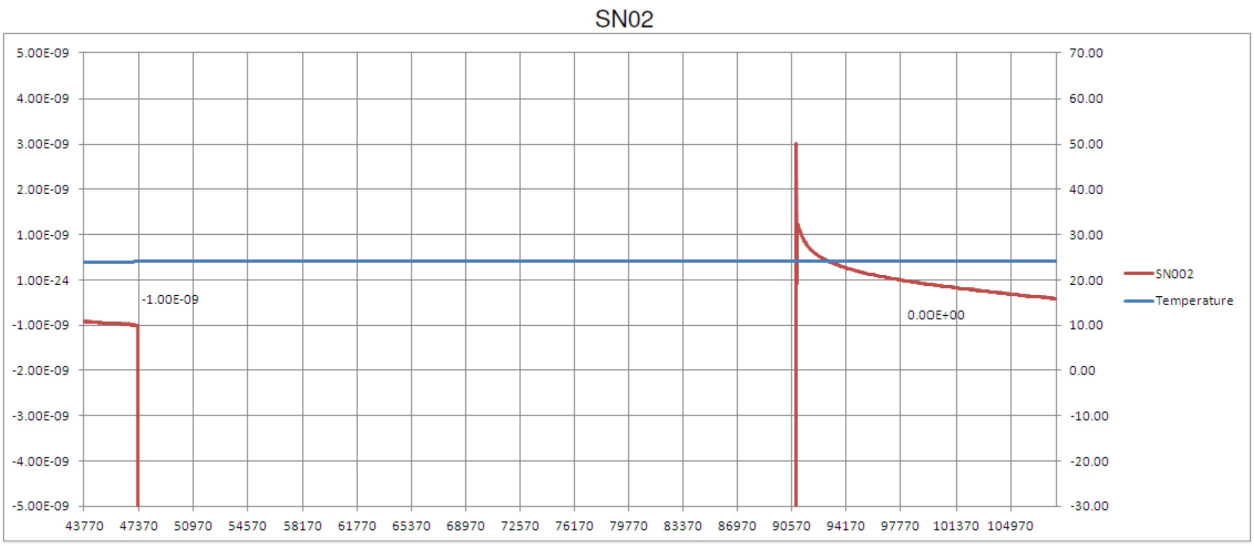


Fig 12: Retrace

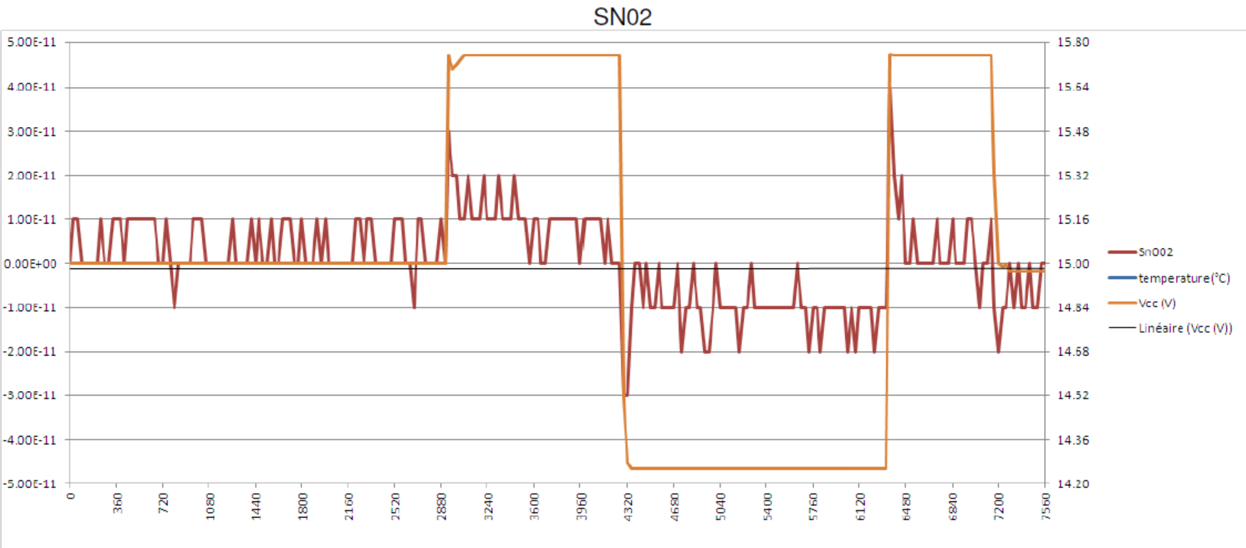



Fig 13 Frequency stability versus supply voltage variation 15V +/- 5%

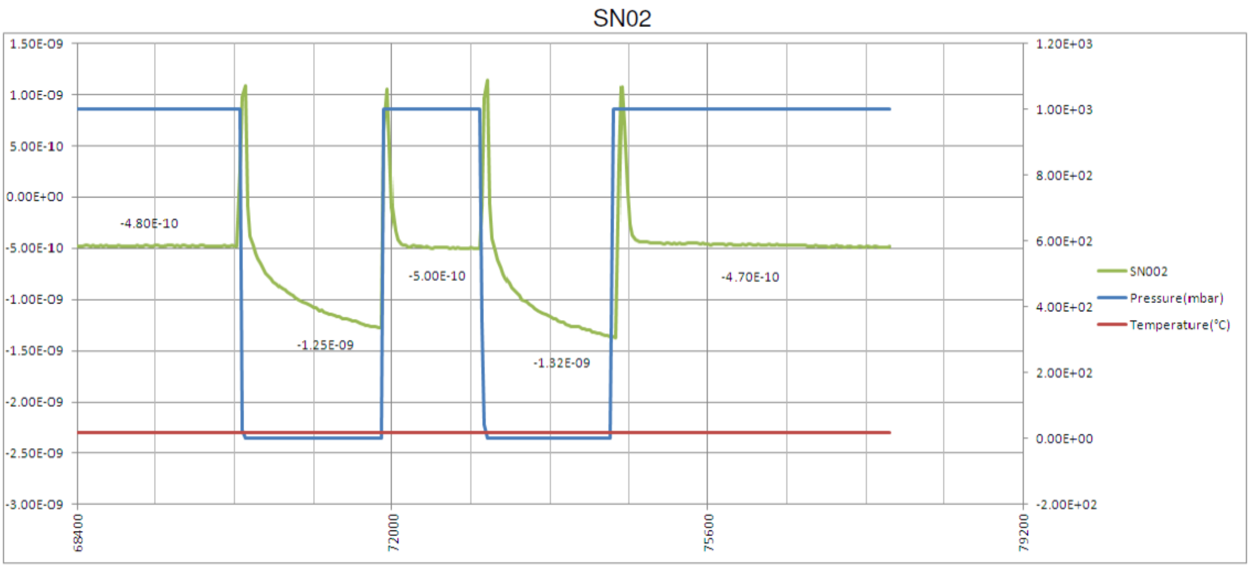



Fig 14: Frequency sensitivity to pressure

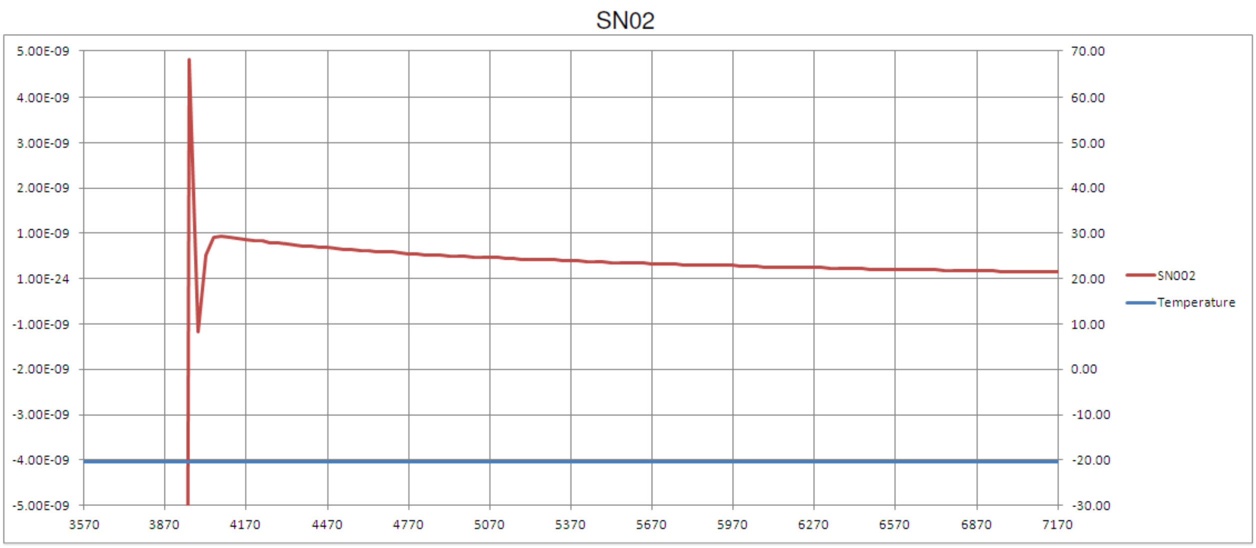


Fig15: warm-up at -20°C

**Environmental tests**

Test during vibration tests at Galileo FOC qualification level

| | | To | After sine Z | After sine X | After sine Y | After random 1 Y | After random 1 X | After random 1 Z |
|---|---|---|---|---|---|---|---|---|
| SN06 | Frequency(Hz) | 98.65 | 98.650 | 98.625 | 98.62 | 98.611 | 98.608 | 98.634 |
| | Vref (V) | 10.0674 | 10.065 | 10.067 | 10.067 | 10.067 | 10.068 | 10.0677 |
| | Level (dBm) | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| | Harmonic (dBC) | -40 | -40 | -40 | -40 | -40 | -40 | -40 |
| | Consumption (mA) | 277 117.7 | 276 118 | 277 116 | 277 118 | 277 117 | 277 115 | 277 118 |
| SN07 | Frequency(Hz) | 99.394 | 99.403 | 99.397 | 99.397 | 99.428 | 99.435 | 99.392 |
| | Vref (V) | 10.0736 | 10.073 | 10.073 | 10.073 | 10.076 | 10.076 | 10.0746 |
| | Level (dBm) | 10.4 | 10.4 | 10.4 | 10.4 | 10.6 | 10.6 | 10.6 |
| | Harmonic (dBC) | -46 | -46 | -46 | -46 | -45 | -45 | -46 |
| | Consumption (mA) | 277 127.9 | 276 129 | 276 130 | 277 129 | 277 127 | 277 124 | 277 125 |

Test during random 2 vibration

| | | To | After random 2 X,Y,Z |
|---|---|---|---|
| SN06 | Frequency(Hz) | 98.665 | 98.665 |
| | Vref (V) | 10.071 | 10.070 |
| | Level (dBm) | 10.7 | 10.7 |
| | Harmonic (dBC) | -40 | -40 |
| | Consumption (mA) | 277 118 | 280 117 |
| SN07 | Frequency(Hz) | 99.437 | 99.416 |
| | Vref (V) | 10.075 | 10.075 |
| | Level (dBm) | 10 | 10.1 |
| | Harmonic (dBC) | -47 | -47 |
| | Consumption (mA) | 277 125 | 280 127 |

**Tests during Mechanical shocks**

| | | To | After X | After X,Y | After Z |
|---|---|---|---|---|---|
| SN06 | Frequency(Hz) | 98.726 | | 98.635 | 98.6 |
| | Vref (V) | 10.067 | | 10.067 | 10.067 |
| | Level (dBm) | 11 | | 11 | 11 |
| | Harmonic (dBC) | -40 | | -40 | -40 |
| | Consumption (mA) | 280 115 | | 270 115 | 270 115 |
| SN07 | Frequency(Hz) | 99.45 | 99.48 | 99.52 | 99.612 |
| | Vref (V) | 10.078 | 10.078 | 10.078 | 10.075 |
| | Level (dBm) | 10.2 | 10.2 | 10.2 | 10.2 |
| | Harmonic (dBC) | -48 | -48 | -47 | -47 |
| | Consumption (mA) | 280 125 | 280 125 | 280 125 | 280 125 |

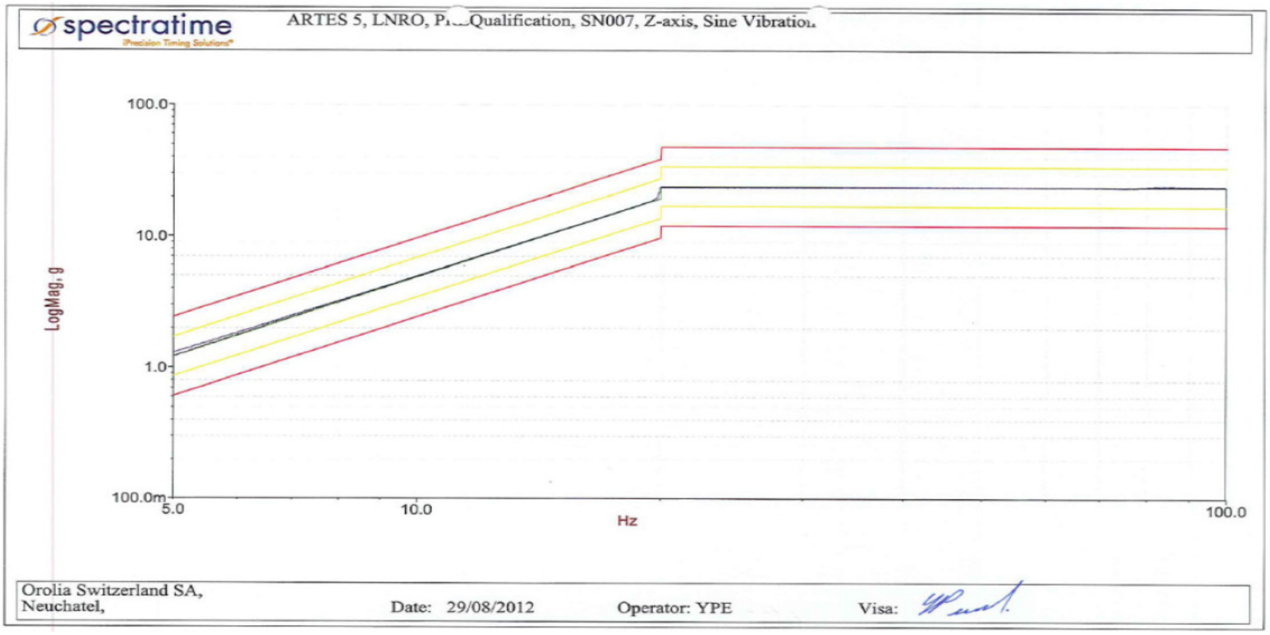



Fig. 16 Sine level applied on the 3 axis: 25g

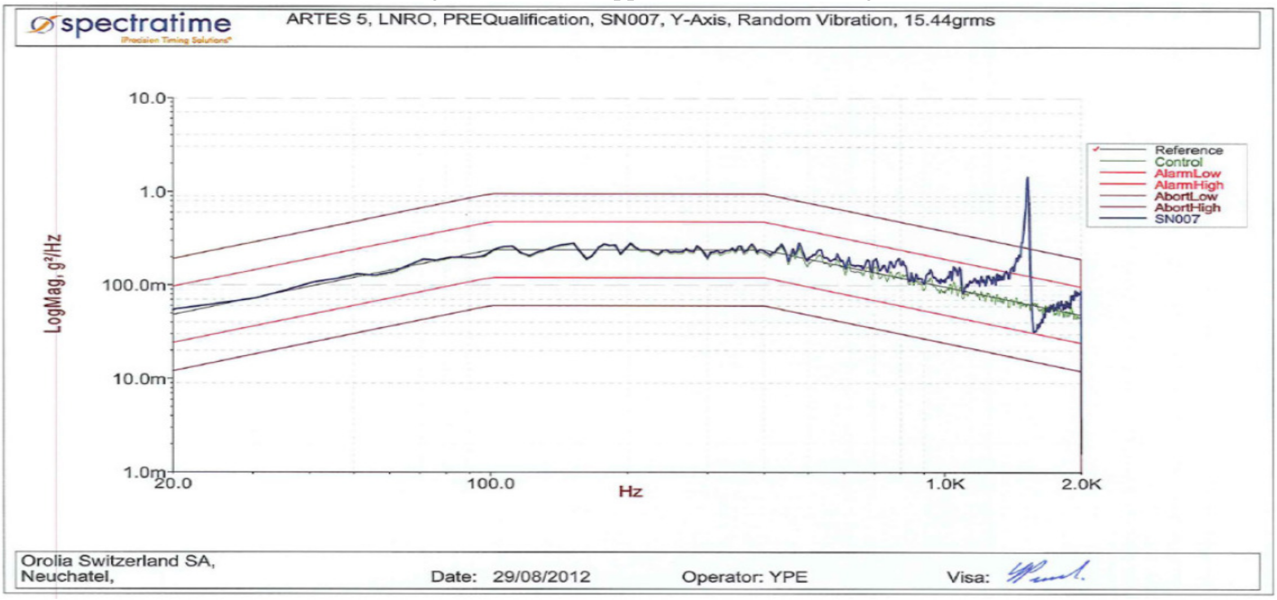



Fig. 17 FOC Random vibration level applied on X and Y axis

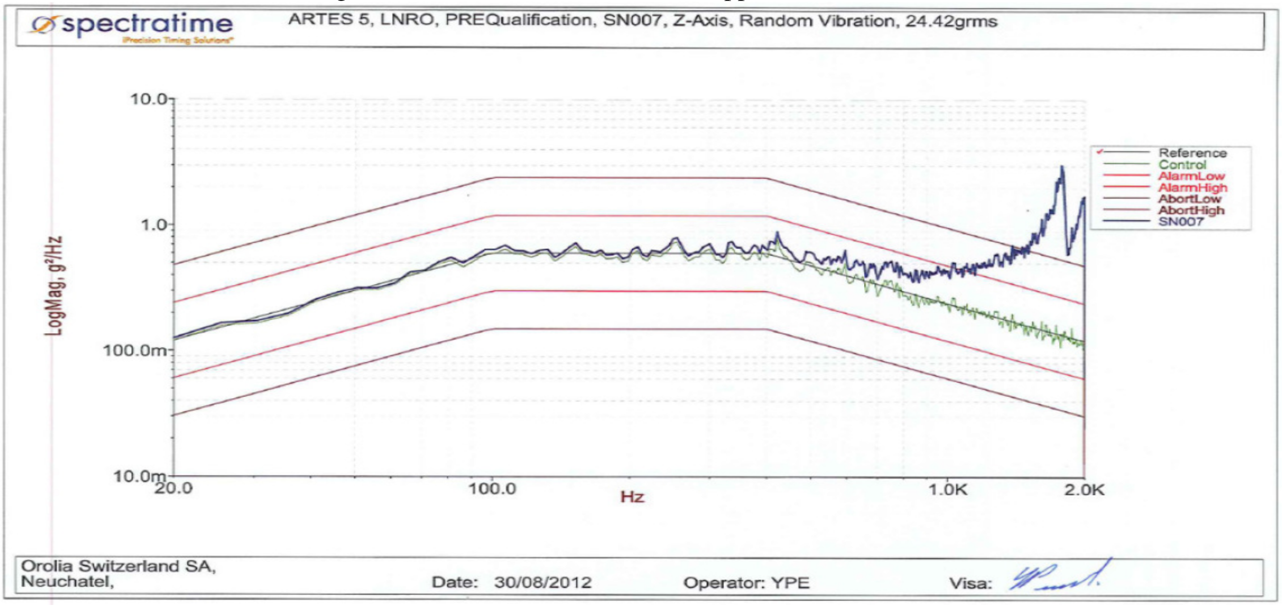



Fig. 18 FOC Random vibration level applied on Z axis

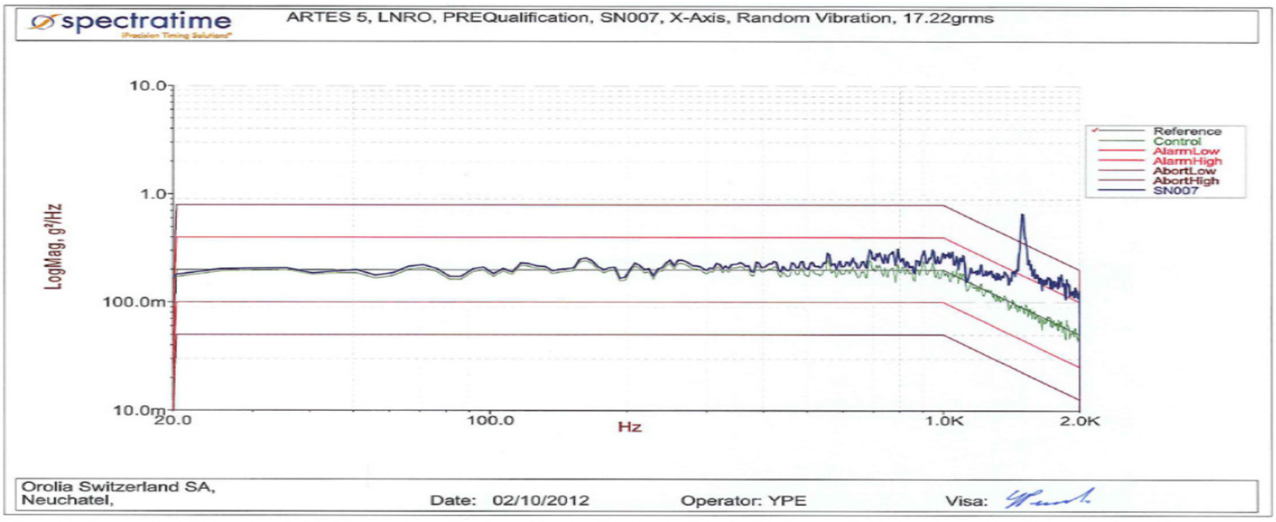



Fig. 19 Random 2 vibration level applied on X and Y axis

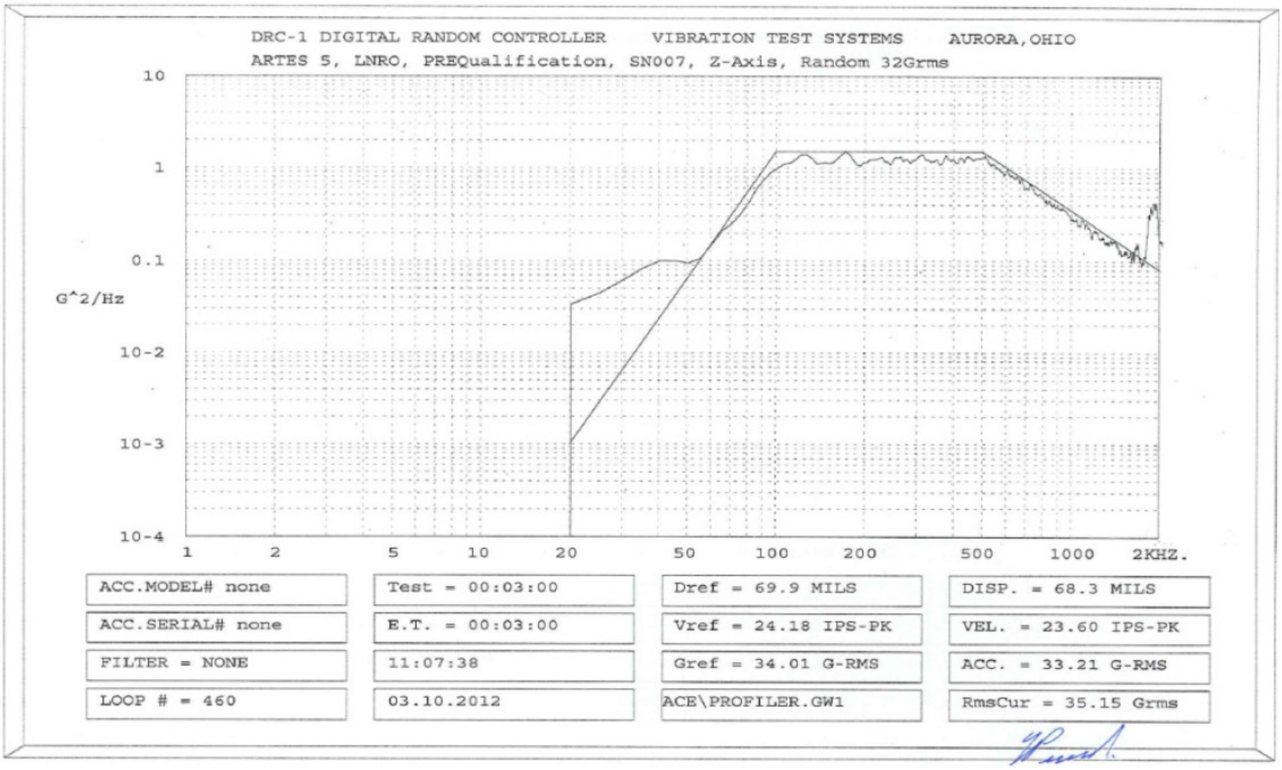



Fig. 20 Random 2 vibration level applied on Z axis

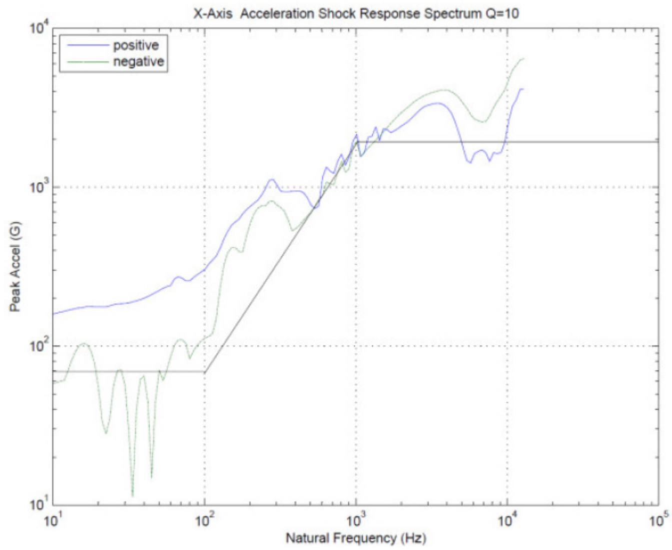



Fig.21 shock in X axis

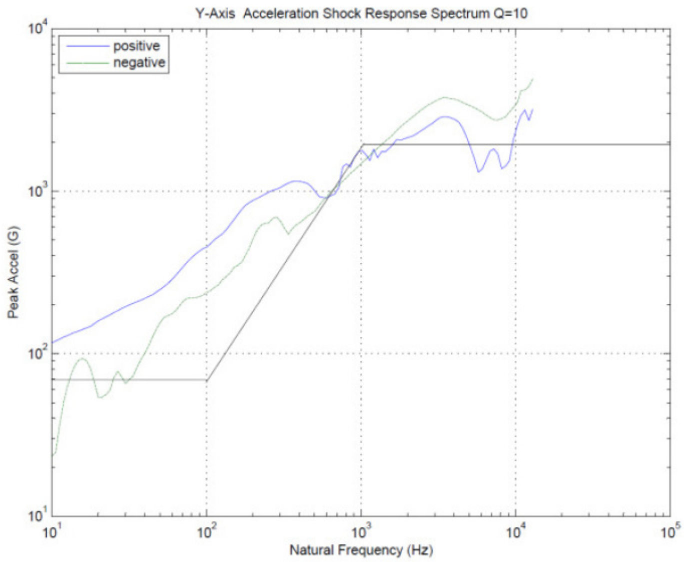



Fig. 22 Shock in Y axis

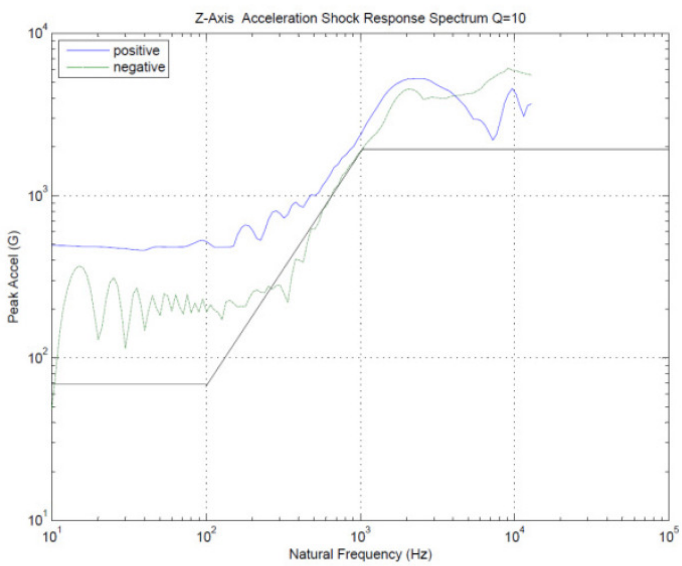



Fig. 23 Shock in Z axis

SN07

| TEST RESULTS | Specification | Initial | Final | Comments |
|---|---|---|---|---|
| | | | | |
| LNRO Serial Number | | SN07 | SN07 | |
| Crystal type | | HC37<br>KVG | HC37<br>KVG | |
| Active parts type | | indus | indus | |
| Output signal under 50Ω | | | | |
| Output signal level(dBm) | 10+/-1 | 10.7 | 10.4 | |
| Harmonics/sub-harmonics(dBc) | -40 | -45 | -48 | |
| Spurious(dBc) 0.1MHz to 1MHz<br>1MHz to 1GHz | <-120<br><-100 | <-120<br><-108 | <-120<br><-108 | |
| Return loss(dB in-band +/-50kHz ) | 15 | 23 | 23 | |
| Frequency accuracy | 1E-8 | <1e-8 | <1e-8 | |
| Frequency adjustment | +/- 2E-7 | +1.9E-7<br>-0.91E-7 | +2.53E-7<br>-0.31E-7 | |
| Frequency stability over life(1) | +/-2E-7 | 1.71E-7 | 1.71E-7 | |
| versus operating temperature range<br>under vacuum | +/-1E-9 | 1E-9 | 1.08E-9 | |
| aging | +/-1.2E-7 | | | |
| sensitivity to Power supply15V+/- 5% per V | | 2.5E-11 | 4E-11 | |
| Sensitivity to load (50 ohms +/-10%) | | 3E-11 | 3E-11 | |
| short term stability(1s) | 1E-12 | 6.7E-13 | 7.2E-13 | |
| sensitivity to magnetic field per Gauss<br>+/- 2 Gauss | 2E-11 | **5E-11**<br>**Y** | **5E-11**<br>**Y** | Compliant in the other directions |
| SSB phase noise (dBc/Hz) | -110<br>-135<br>-150<br>-160<br>-160<br>-160 | -112<br>-141<br>-154<br>-164<br>-168<br>-169 | -112<br>-140<br>-154<br>-164<br>-168<br>-169 | |
| Power consumption(W) -20°C<br>+60°C | 2.5W<br>1W | 1.475<br>0.715 | 1.435<br>0.68 | |
| Power consumption during warm-up at -20°C | 4W | **4.63** | **4.65** | |
| Warm-up time at -20°C | 30min | 7 | 7 | |
| Retrace | +/- 5E-9 | 5.9E-10 | 3.5E-10 | |
| Start up time at -20°C | 10s | <1s | <1s | |
| Mechanical resonance (Hz) | | | | |
| X axis | | 881 | 876 | |
| Y axis | | 860 | 863 | |
| Z axis | | 1942 | 1832 | |
| | | | | |
| | | | | |
| Dimensions(cm3) | 75 | 75 | 75 | |
| Mass(g) | 100 | 98 | 98 | |

Note 1: as aging isn't measured on EM we will take worst case condition for calculation, +/-1.2E-7 for aging and +/-5E-8 for radiation.

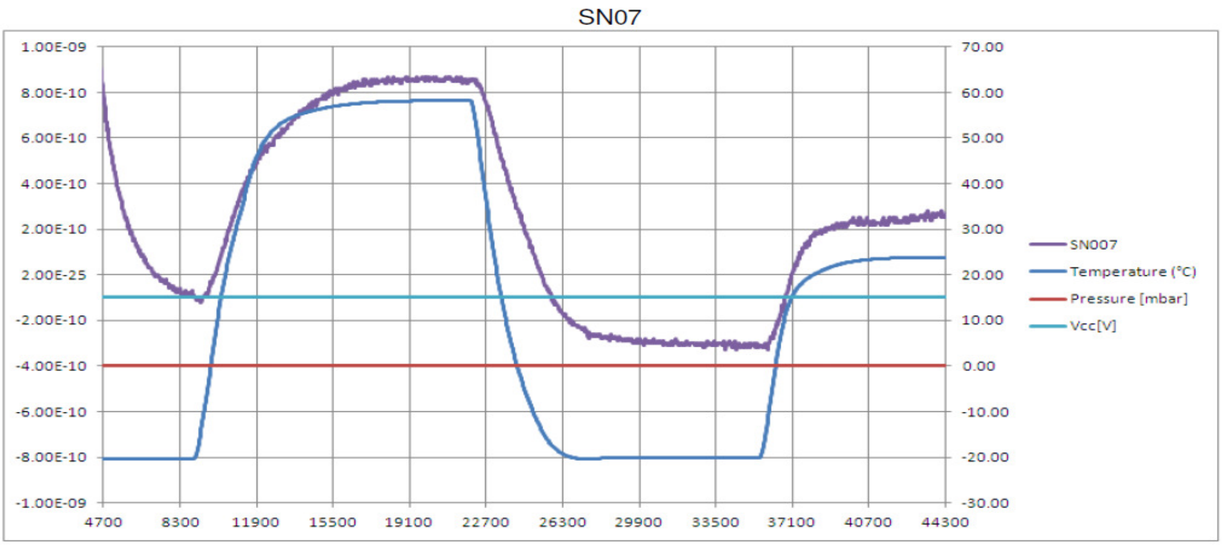
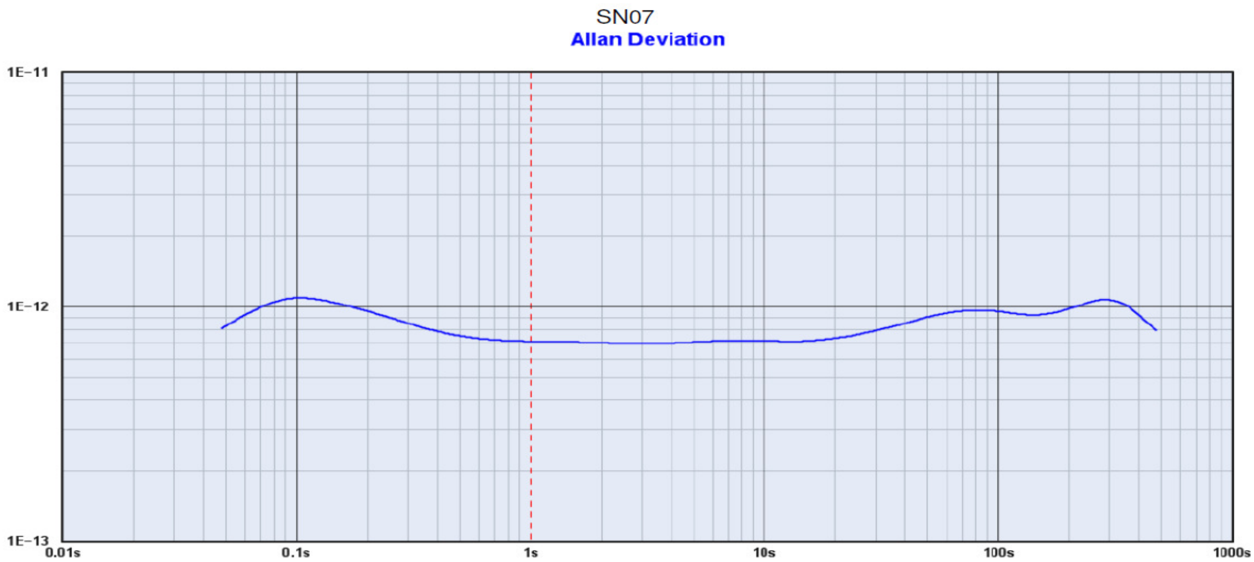



Fig. 24 Frequency stability versus temperature




| Trace | Notes | Input Freq | Input Amplitude | Ref Amplitude | Sample Interval | ADEV at 1s | Duration | Acquired |
|---|---|---|---|---|---|---|---|---|
| LNRO SN007 final Vc−10V | | 10.000 MHz | 11 dBm | 12 dBm | 0.047 s | 7.16E−13 | 30m 0s | 38011 pts |

Fig. 25 Short term stability

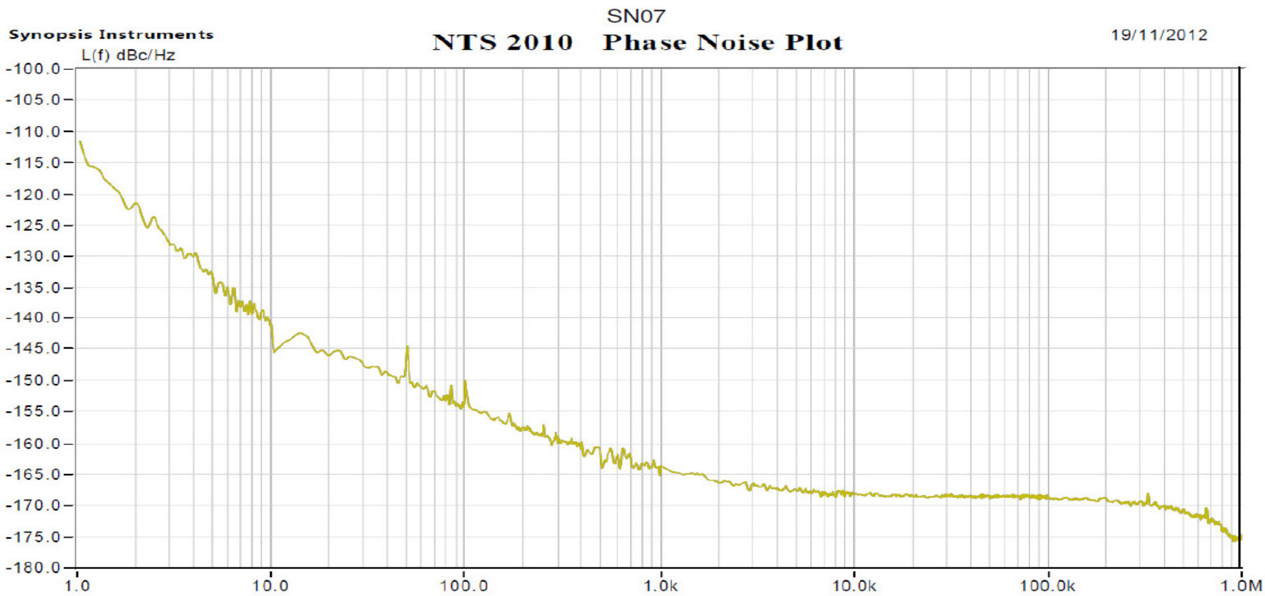



Fig. 26 Phase noise

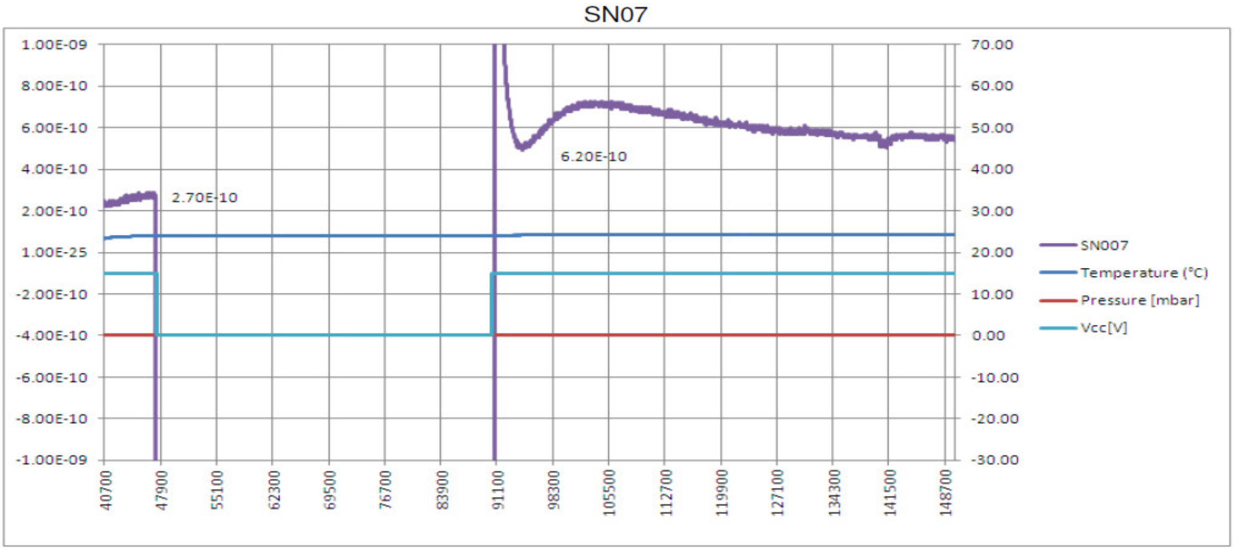



Fig. 27 Retrace

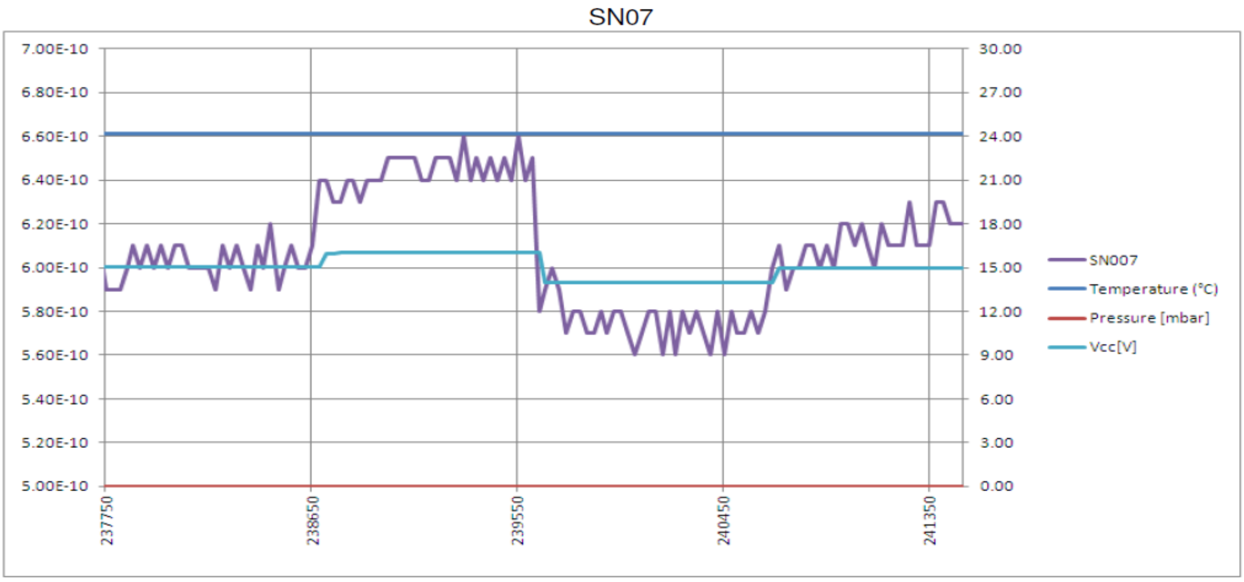



Fig. 28 Frequency stability versus Supply voltage variation 15V+/- 5%

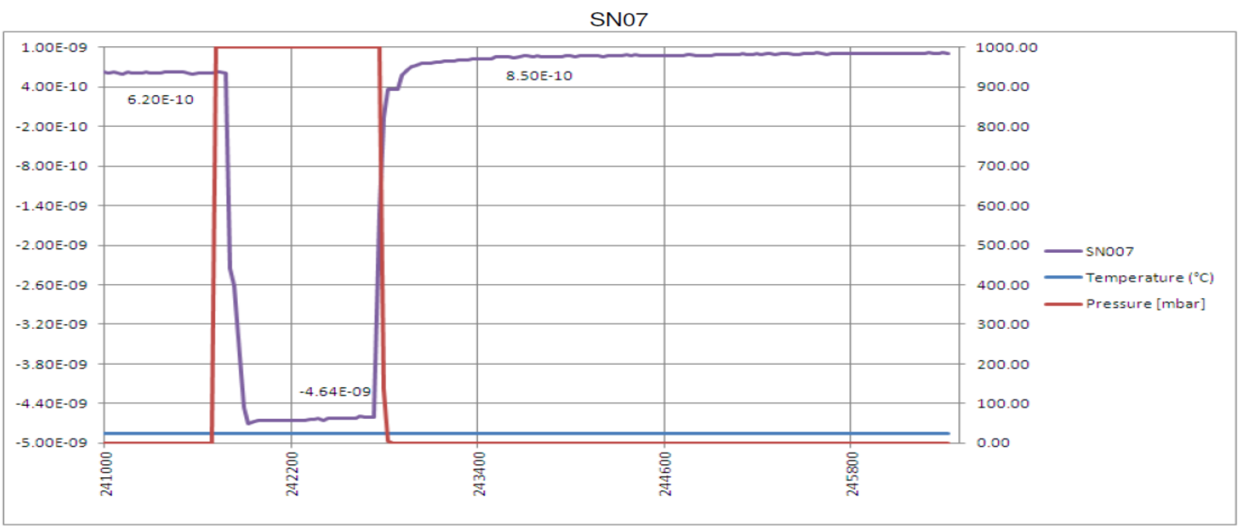



Fig. 29 Frequency sensibility to pressure

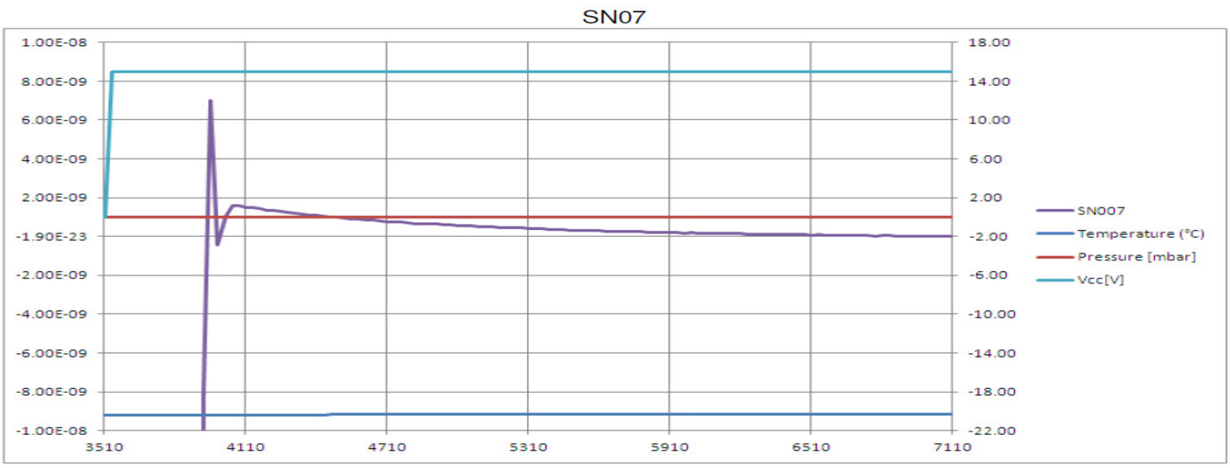



Fig. 30 Warm-up at -20°C

**Task 7: Overall Assessment and Recommendations**

LNRO HC37 design has given 100% compliance versus targeted specification, SpT preferred solution.
Warm up power consumption isn't a real non compliance. Since we have a wide margin on warm up duration, heating power can be reduced.

LNRO HC40 design has to be modified in order to improve it stability versus temperature range. The oven will be redesigned like the HC37 design.

All units have successfully passed the qualification tests, no degradation between initial and final tests.
Some modifications have to be applied on the LNMO design in order to improve it assembly and tuning parts accessibility:

- The oven for HC40 crystal has to be modified in order to improve the frequency stability versus temperature range. As for the HC37U crystal the oven has to be closed..
- Minor PCB modifications in order to improve:
  - tuning parts accessibility , increase pads size
  - heating power transistor wiring , increase pads hole diameter
  - output connection wiring, move pads connections of 1mm
- all these modifications will improve the LNMO manufacturability without compromising the performances achieved on EMs

LNMO Cost and Competition Status Assessment
LNMO design covers all identified demands in term of performances and cost.
Conditions:

- Parts procurement for a minimum of 50 units
- Units manufacturing by minimum quantity of 20

**CONCLUSION**

**Design**
LNRO HC37 design has given 100% compliance versus targeted specification, SpT preferred solution (Warm up power consumption isn't a real non compliance. Since we have a wide margin on warm up duration, heating power can be reduced).
LNRO HC40 design has to be modified in order to improve it stability versus temperature range. The oven will be redesigned like the HC37 design.

**Preliminary qualification tests**
All EM have successfully passed the preliminary qualification tests, no degradation between initial and final tests.

**Cost and Competition**
LNRO design covers all identified demands in term of performances and cost with below conditions:

- Parts procurement for a minimum of 50 units
- Units manufacturing by minimum quantity of 20

2 projects have been won against European competitors and a preliminary specification has been issued, see next pages.

10 October 2012

**PRELIMINARY**

***Crystal-Based Low Noise Master Oscillator (LNMO)***

# Space Low Noise & Performance Source

The LNMO is a cost-effective, high-performance master crystal oscillator. It's designed with long-lifetime, high-reliability technology for advanced space applications.

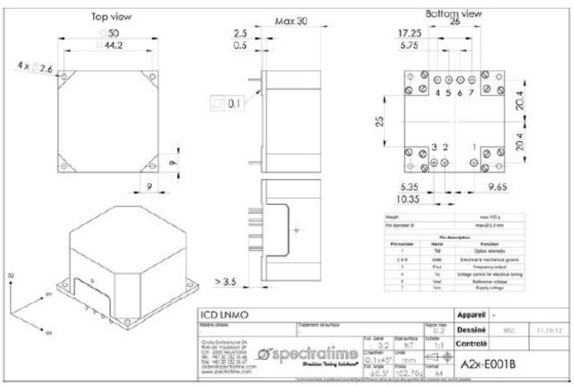
**Key Features**

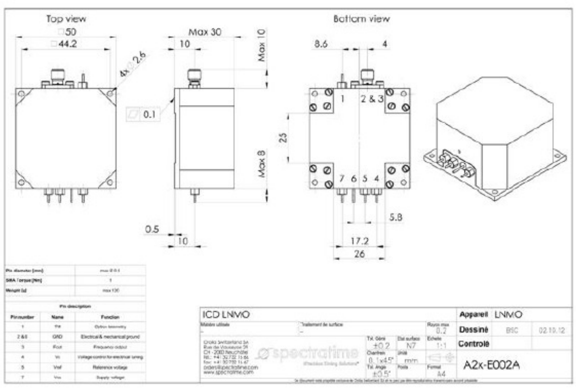
- Very small mass and volume
- Low noise
- Low power consumption
- Low temperature sensitivity
- Excellent short and long term stability
- Fast warm-up
- Wide operating temperature
- Pre-adjusted frequency and/or voltage controlled
- Frequency Range: 5MHz to 40MHz
- Supply voltage: 12V or 15V
- Rad tolerant up to 100krad

**Applications**

- Navigation
- GPS receivers
- Down and Up Converters
- Transponders
- FGU
- Board Calculator
- Synthesizer
- SAR

**LNMO external dimensions (2 versions available)**



# iSource+® Space-Qualified LNMO Specs

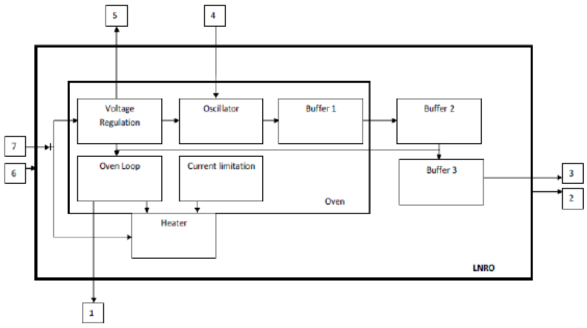
## SPECIFICATIONS

| Type | A2x-S001 at 10MHz | | |
|---|---|---|---|
| Parameter | Value | | |
| Dimensions | 50x50x30 mm | | |
| Output signal frequency | 10 MHz* | | |
| Frequency long term stability, 1st year | < $\pm 3 \times 10^{-8}$ / year | | |
| Average ageing per day after 1 month | < $\pm 1 \times 10^{-10}$ / day | | |
| Frequency long term stability, years after | < $\pm 1 \times 10^{-8}$ / year | | |
| Frequency short term stability | < $1 \times 10^{-12}$ (0.1-10 s) | | |
| Frequency stability over full temp. range | < $\pm$ $1 \times 10^{-9}$ | | |
| Frequency adjustment | > $\pm$ 2.5 Hz | | |
| SSB phase noise assuming 10MHz carrier | ULN (dBc/Hz) | LN (dBc/Hz) | Standard (dBc/Hz) |
| 1 Hz | < -110 | < -105 | < -100 |
| 10 Hz | < -140 | < -135 | < -130 |
| 100 Hz | <-150 | <-145 | < -140 |
| 1000 Hz | <-160 | < -155 | < -150 |
| 10000 Hz | <-168 | < -165 | < -160 |
| Output signal level | 7 dBm ± 1<br>Up to 10 dBm on request | | |
| Output impedance | 50 Ω ± 10% | | |
| Harmonics | -40 dBc | | |
| Spurious signals | -120 dBc | | |
| Power consumption during warm-up | Standard<br>4W | Fast<br>6W | |
| Nominal power consumption | 1.5 W | | |
| Maximum power consumption in operation | 2.5 W | | |
| Volume | < 75 $cm^3$ | | |
| Power supply | 12 V | 15V | |
| Warm-up time (accuracy < $\pm 2 \times 10^{-8}$ at 25°C) | Standard<br>10 minutes | Fast<br>5 minutes | |
| Mass | 100 gr | | |

| Type | A2x-S001 at 10MHz | | |
|---|---|---|---|
| Parameter | Value | | |
| Connection: Power, RF Output, Control voltage, Ref Voltage, TM | 7 solderable pins<br>or<br>5 solderable pins +SMA | | |
| Mechanical interface<br>Mechanical fixation | flat base plate<br>4 x M2 screw | | |
| Max. base plate operating temperature | 70 °C | 60°C | 50°C |
| Min. base plate operating temperature | -30°C | -20°C | 0°C |
| Storage temperature | -40 to 85 °C | | |
| First natural resonance | > 800 Hz | | |
| Random Vibration tested, with axis perpendicular to the mounting plane. 20 - 100 Hz<br>100- 500 Hz<br>500- 2000 Hz<br>Duration | +9dB/oct<br>1 (1.5) $g^2$/Hz**<br>-6 dB/oct<br>60 (180) sec/axis** | | |
| Random Vibration tested, with axis parallel to the mounting plane. 20 - 1000 Hz<br>1000 - 2000 Hz<br>Duration | 0.14(0.22) $g^2$/Hz**<br>-6 dB/oct<br>60 (120) sec/axis** | | |
| Sinusoidal vibration 5 - 20 Hz<br>20 - 100 Hz<br>Sweep rate | 11 mm 0-peak<br>25 g<br>2(1) oct/min.** | | |
| Life time / MTBF | 15 years/9 Mio hrs | | |
| Pressure sensitivity vacuum to atmosphere (thermal effect) | < $\pm 5 \times 10^{-8}$<br>@25°C | | |

* Other frequencies (5 MHz to 40 MHz) and related specifications available upon request.
** Values in brackets only applicable for qualification testing

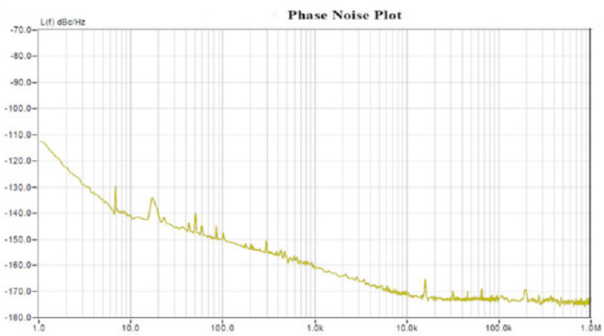
## FUNCTIONAL BLOCK DIAGRAM OF THE LNMO




1- Optional telemetry output
2- RF GND output
3- RF output
4- Control voltage input
5- Voltage reference output
6- Supply GND input
7- Supply Voltage input

## Typical LNMO Phase Noise

**LNMO Phase noise at 10MHz**




**LNMO Phase noise at 5 MHz**