Proceedings of the 2003 IEEE International Frequency Control Symposium and PDA Exhibition
Jointly with the 17th European Frequency and Time Forum

Poster session
Group 2.A

THE SIGNIFICANT IMPROVEMENT OF BASIC OCXO FOR TIME AND FREQUENCY STANDARDS

YAKOV L. VOROKHOVSKY, SERGEY V. ANASTASYEV,
ALEXANDER A. VOLKOV

Morion, Inc.: 13a KIMa Avenue, St. Petersburg, 199155, Russia

The main target of this project was a significant improvement of short-term stability of basic OCXO designed with Internally Heated Quartz Resonator (IHQR). Also, because of the required very long "life time" of new OCXOs (> 10 years), the total operational stability must be accordingly improved to be for sure compensated inside of pulling range.

We remained on the IHQR-based concept of OCXO because of very restricted power consumption. The sources caused the short-term instability have been explored. As a key of them was found a PTC thermistor being a temperature sensor and mounted on the holder of quartz blank (i.e. inside of IHQR). Then the following improvements in 5 MHz OCXO's design were implemented:

(1) The move away from 5th overtone of AT cut to the 3rd overtone of SC cut being much less sensitive vs. "noisy" sensor of thermocontroller;
(2) The move away from PTC thermistor as a sensor to the NTC thermistor covered by glass;
(3) The combination of both a.m. (1) and (2).

As a result an advanced 5 MHz OCXO was created with the following main data:

- Stability vs. operating temperature …… $< \pm 5 \times 10^{-9}$
- Short-term stability (Allan Variance)
  for 1s…10s, options …… $< 1 \times 10^{-12}$
  ……..$< 2 \times 10^{-12}$
- Phase noise: at the 1 Hz offset ……< -115 dBc/Hz
  floor ……< -158 dBc/Hz
- Aging slope ……..…$< \pm 1 \times 10^{-10}$ /day
- Total stability for 10 years of operation
  (incl. temperature change, aging, etc.) ……...$< \pm 1 \times 10^{-7}$
- Pulling range ……$> \pm 2.5 \times 10^{-7}$
- Power consumption ……... < 0.4 W
- Warm-up time ……< 3min
- Size/Weight …… 2″ x 2″ x 1″/75gr

Introduction

This paper is devoted to some aspects of OCXO application in an output stage of atomic frequency standard. The specific requirements that the OCXO must meet are excellent short-term frequency stability and good total operational stability during very long "life time". Also, we consider the low power consumption of the OCXO as a very important feature particularly for autonomous and Space applications. The main target of this project was a significant improvement of short-term stability of basic OCXO designed with Internally Heated Quartz Resonator (IHQR), [1].

Effects cause the frequency instability

We investigated currently produced 5 MHz OCXO based on IHQR with AT-cut 5^{th} overtone blank. This oscillator demonstrates short-term stability not better than 5E-12 (Allan variance for 1s). First, it was defined that maximum of spectrum density of frequency fluctuations had been situated between 1 and 20 seconds. Considering that thermal time constant of the oven construction of IHQR is approximately 10 sec, we supposed that the instability had been caused by the noise of thermocontroller. Then we defined the source of the noise. PTC thermistor, used as a sensor, had an increased noise. As the frequency of AT-cut crystal is very sensitive to thermal gradient, the noise of thermocontroller decreases short-term stability significantly.

To identify the contribution of PTC sensor's noise to frequency instability an additional NTC sensor was installed in IHQR. OCXO with this "experimental" IHQR was built and short-term stability was measured when the PTC and NTC sensors were turned on. To get comparative results the thermal gain of the oven in both cases was established equal. We got the following results: for PTC sensor-Allan variance for 1s was about E-11, for NTC sensor - Allan variance for 1s was about 2E-12. The results showed that short-term stability of such type of OCXOs could be significantly improved.

Technical solution

It became obviously there are some ways of improvement of short-term stability of IHQR based OCXOs, i.e. following:

1) to replace the PTC sensor by low noise NTC thermistor,
2) to use SC-cut blank instead of very sensitive to thermal gradient AT-cut,
3) to use the combination of a.m. items 1 and 2.

We built OCXOs according to each of mentioned items. For 5 MHz AT-cut 5^{th} overtone crystals with NTC sensor Allan variance for 1s was (1.5-3.5)E-12. Other parameters did not differ from the parameters of initial OCXO designed with PTC sensor.

For 5 MHz SC-cut 3^{d} overtone blank we got significantly better results even with original PTC sensor. This version of OCXO demonstrated Allan variance for average time 1…10 s up to 5E-13. The main parameters of the corresponding OCXOs are:

Frequency stability vs. temperature range -20…70^{o}C……<±5E-9
Short-term stability (Allan variance) for 1…10s,options…….<1E-12
<2E-12
Phase noise: 1Hz offset……<-115dBc/Hz
Floor……. -158dBc/Hz
Aging slope ……..…<±1E-10/day

Total frequency stability for 10 years of operation
(incl. temperature change, aging,etc.)……..… <±1E-7
Pulling range ……..… >±2.5E-7
Power consumption …… <0.4W
Warm up time ……..…<3min
Size/Weight ……..….2”x2”x1”/75gr.

Fig.1 and Fig.2 represent typical data of short-term stability and phase noise.

Fig. 1.

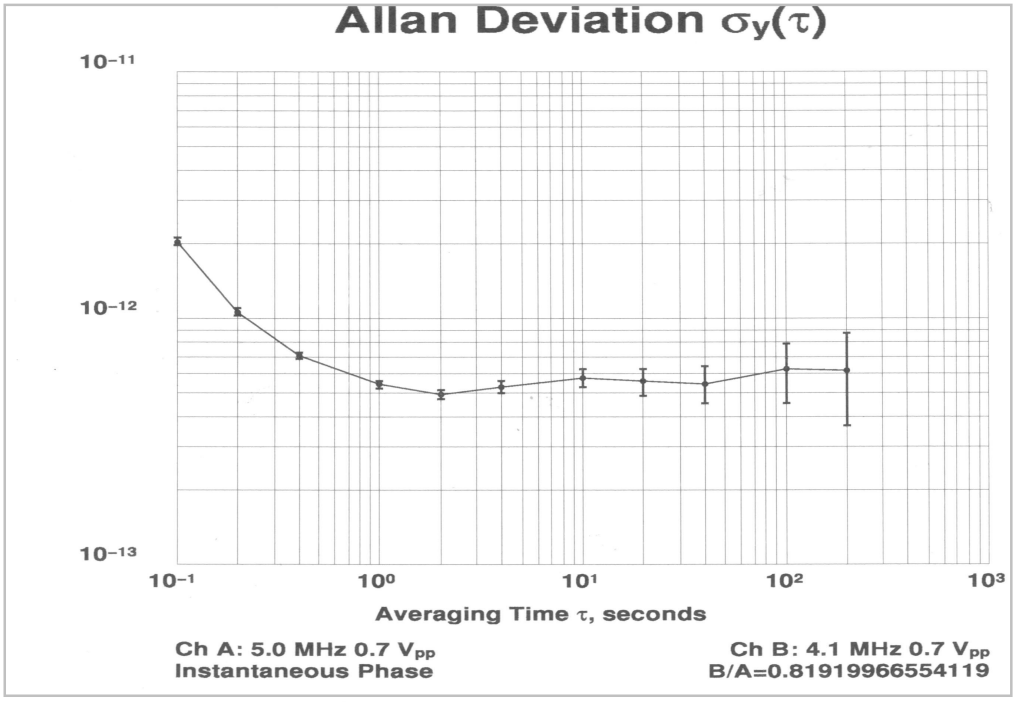
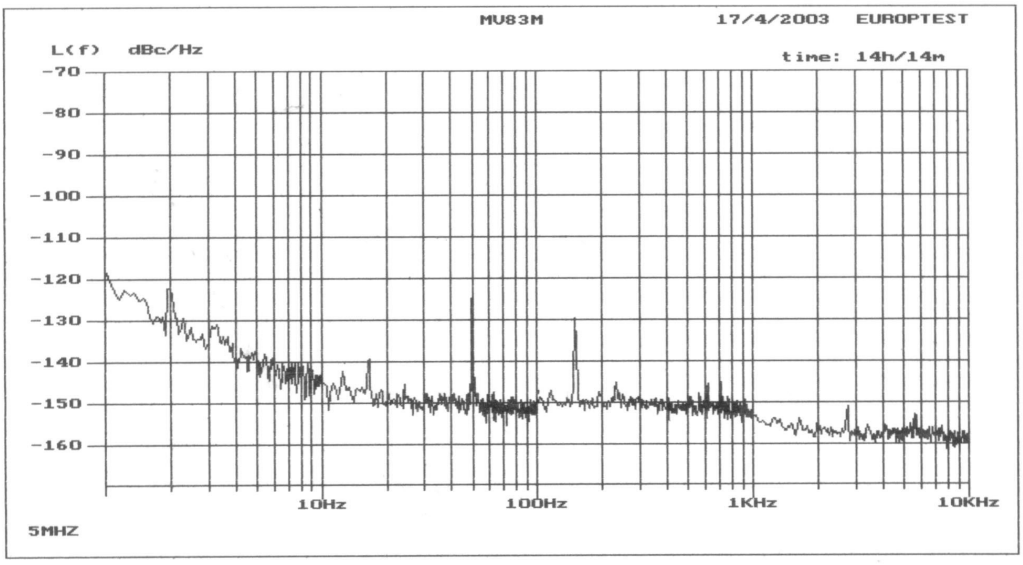


Fig.2



The combination of SC-cut blank and NTC sensor has not noticeable advantages compared to previously described version. It means that SC-cut blank is much less sensitive to thermal gradients than AT, and in this case short-term stability is limited by other factors.

Conclusion

In the course of carrying out of this work the main source of short-term instability of IHQR-based OCXOs was defined. Ways of improvement of short-term stability were also worked out. The IHQR-based OCXO with the parameters meeting the requirements for time and frequency standard applications was created. This type of OCXO is currently produced at MORION, Inc.

The achieved level of short-term stability for average time 1…10 s in IHQR-based OCXO is practically the same as for double oven OCXO (DOCXO) based on precision cold weld crystal [2] but the power consumption of IHQR-based OCXO is much less proving significant advantage for corresponding applications.

References

[1] Y.L.Vorokhovsky, B.G.Drakhlis. High-stability quartz oscillators on internally heated quartz resonators with AT and SC cuts. - Proc. of the 45th Annual Symposium on Frequency Control, Los Angeles (CA), USA,1991, pp.447-451.

[2] S.V.Anastasyev, A.A.Volkov, Y.L.Vorokhovsky. A New High Stability DOCXO - Statistics of the Results of Frequency Stability Measurements. –Proc. of 2002 IEEE International Frequency Control Symposium & PDA Exhibition. New Orleans, Louisiana, U.S.A. 2002, pp.633-638.

Dr. Yakov L. Vorokhovsky, Sergey V. Anastasyev, Alexander A. Volkov
Morion, Inc.
13a KIMa Avenue, St.Petersburg, 199155, Russia,
Tel +7 812 350-7572, Fax +7 812 350-7290
E-mail: yakov@morion.com.ru