"Atomic" accuracy low power crystal clocks for ocean seismic exploration

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Introduction.

Modern equipment for underwater oil seismic exploration demands very accurate clocks for high precision timing of the ocean bottom nodes.

Aside from utmost time accuracy, minimal power consumption of the clocks is the other crucial parameter, which to a great degree, limits operation duration of the nodes between the battery recharge and re-synchronization.

Up to now, the chip scale atomic clocks (CSAC) providing very high accuracy at low power consumption and small packaging have remained unbeatable solution for such applications.

Meantime, recent progress in the OCXO technology based on the internally heated resonator (IHR) concept has enabled creation of extraordinary devices combining "atomic" frequency stability and low phase-noise level with miniature sizes and extremely low consumption.

Xtal Ball Technologies presents below its top IHR oscillators in comparison with the most advanced CSAC models.

Construction of modern IHR oscillators

A design of the IHR oscillators (IHRO), a pacemaker of the crystal clock, is grounded on TO-8 packaged (IHR) integrating in the evacuated volume the crystal plate together with the whole heating structure. The IHR unit is mounted on the unheated PC board bearing the rest oscillator circuitry, which can be used uncovered, with DIP14 compatible sizes and pins-out, or sealed hermetically in the compact steel case (fig. 1)

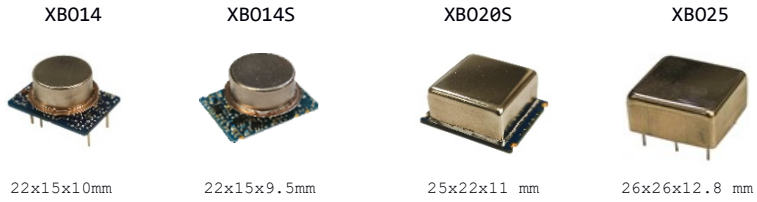

Fig. 1. External view of the IHR oscillators: DIP14 compatible XBO14 and XBO14S (SMD) models, ultra-stable XBO20S and XBO25 models.

Basic performances of the novel IHR oscillators

Excellent thermal isolation of the IHR inner structure from environment along with improved vacuum conditions and application of sophisticated compensation circuitry have ensured extremely high **long-term** and **temperature stability** of the IHROs, not yielding to these parameters of CSACs (fig. 2,3).

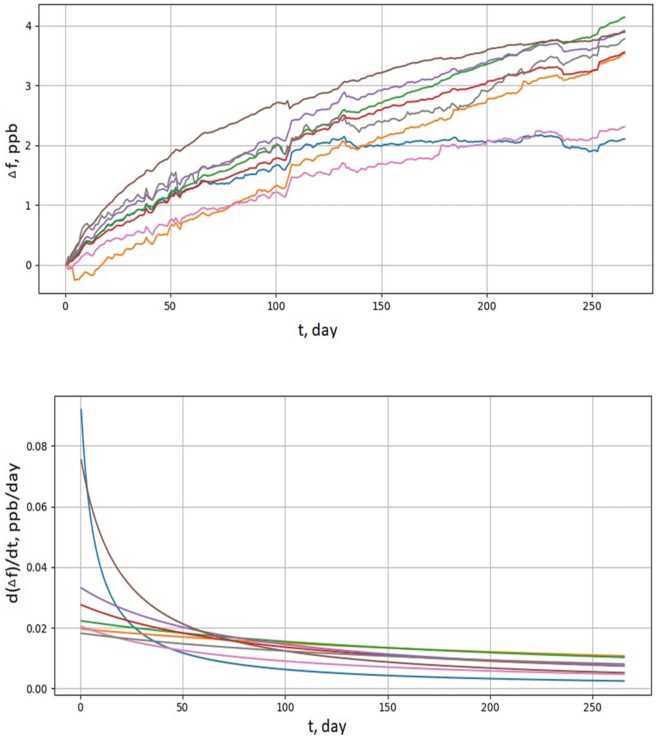

Fig. 2. Aging behavior of the novel IHROs:
a) frequency vs. time drift; b) aging vs. time rate (calculated)

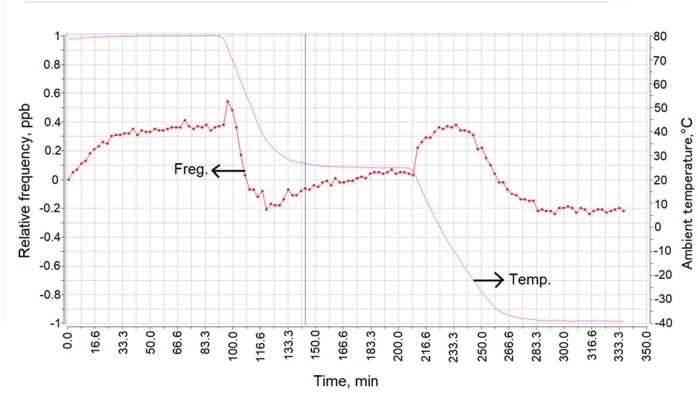

Fig. 3. Frequency vs. temperature of the XBO20S, XBO25 models over (-40 +80)℃ range.

In difference from the atomic clocks, **power consumption** of the IHROs is in high dependence on the internal temperature of the IHR, which is usually set a few degrees above the upper range bound. Table 1 depicts typical consumption of the IHROs at 25°C for some operational ranges.

Table 1. Power consumption of the IHROs at different operational temperature ranges

Operational range, °C	0 +50	-10 +60	-30 +70	-40 +85
Power consumption at 25°C, mW	65	75	85	100

Out of the table, at (0 +50)°C range, most applicable at the submarine exploration, the IHROs consume only 65 mW, that gives them considerable advantages over CSACs.

Main superiority of the IHROs over the atomic clocks are their excellent **short-term stability** and **phase-noise** performances (fig. 4, 5) proceeding from high Q-factor of the crystals and minimization of all the flicker factors.

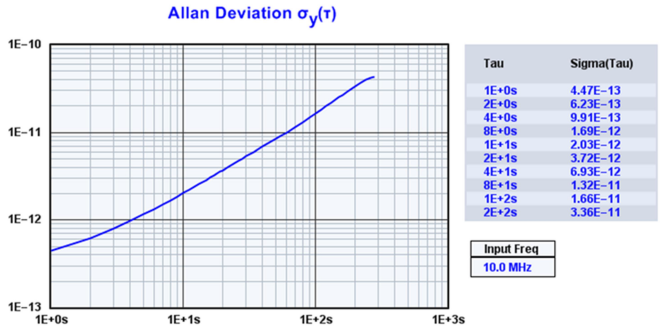

Fig.4. Typical Allan deviation of the 10 MHz IHROs

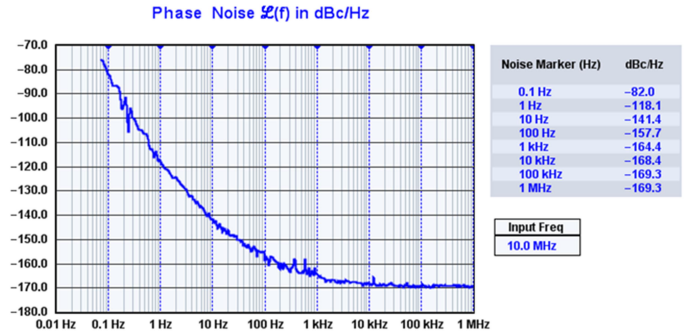

Fig. 5. Typical phase-noise pattern of the low-noise 10 MHz IHROs.

Comparison of CSACs and novel IHR oscillators

Basic characteristics of the IHROs are summarized in table 2 in comparison with the CSAC models (www.microchip.com).

Out of the data, the XBO20S & XBO25 and top SA.65S models perform close the long-term and temperature stability values. The IHROs, at that, provide much better short-term stability and phase-noise level having smaller sizes and power consumption, especially at the narrow temperature range.

Table 2. Main performances of the top IHROs and CSAC models (operation at 10 MHz)

Performances	XBC20S & XBC25	SA.65	SA.45S
Operation frequency, MHz	8-100		
Operation temperature range, °C	-40 +80	-40 +80	-10 +70
Temperature stability around 25°C, ppb	±0.5	±0.3	±1
Aging (typical), ppb/month	0.9		
Allan deviation, τ=1s	4E-13	3E-11**	3E-10
Power consumption at 25°C, mW	<100 65*	120	
Package volume, ccm	<9	17	

*for (0+50)°C operational range; ** at 1000 s average time.

Conclusion

The "atomic" frequency stability associated with excellent phase-noise level and very low power consumption make the novel IHROs very prospective reference for wide range of high performance equipment, such as battery power instrumentation, high-end navigation, mobile radars, and others.

At narrow operational temperature range, the IHROs ensure extremely low, down to 65 mW, power consumption. This advantage along with smaller sizes and cost factor make them a prospective alternative to the low power atomic clocks at timing of high precision ocean bottom nodes.