A Wide Frequency-regulated Precision OCXO

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Abstract— **High precision OCXO based on SC cut overtone crystals can show very high frequency stability and aging. However, its frequency regulation range by voltage control is not wide. When high precision OCXO is used as the standard of precise controllable measuring instruments, especially the precision slave VCOCXO, in allusion to widen frequency comparison range, the precision OCXO should not only show nice frequency stability and aging, but also can be regulated and controlled in a relative wide frequency range. Using a fundamental crystal it is impossible to obtain this result. In allusion to wider frequency regulation range, we propose a new method through regulating the control temperature of the OCXO. With this way all the good performances of precision OCXO are kept, and, at the same time the original 10^{-7} order voltage-controllable frequency range is improved into 5×10^{-6} or wider.**

I. INTRODUCTION

As the phase-locked source of phase noise measurement, it not only should show good phase noise specifications and high stability, but also the reference signal of the oscillator should be locked steady by another host source in a relative wide frequency range at the same time.

The frequency stability of overtone crystals is better than that of fundamental ones, and SC cut crystal oscillators are better than AT cut ones, so if we need both of the nice frequency stability and aging specifications, SC cut overtone crystal oscillators are more suitable. However, SC cut crystal oscillators show a poor frequency pulled character. A lot of experiments show that the frequency regulation range by voltage control to high precision OCXO only at 10^{-7}order. It will be confined in some fields that request a wide frequency control range [1]. The method used widely is π grid method or other circuit processing, but this will take down the Q value of the whole circuits, and has a great influence over the frequency stability [2]. The frequency-temperature change of overtone crystal can reach 10^{-5} order range between turn point and room temperature.

II. BASIC AND LOCKING EXPERIMENTS OF OVERTONE CRYSTAL OCXO

The temperature of the OCXO is controlled by electric bridge that includes a thermistor Rt, shown by Fig.1. When the resistance of Rx is changed, the resistance of thermistor should be the same to keep the balance of the electric bridge. Because the resistance of the thermistor is relevant to the temperature, the temperature of OCXO can be changed by Rx resistance [3].

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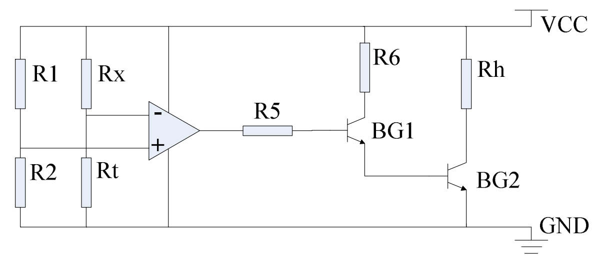

Figure1. Temperature control bridge of OCXO

We use a SC cut high-stability OCXO to test the temperature influence to its frequency and the possibility to be utilized. The crystal is made specially to show higher nominal frequency at its turn point. It shows the different frequencies at 25℃, and turn point, 9.9998826 MHz and 10.0000232 MHz respectively. The room temperature, starting up temperature, is 25℃ and turn point is 85℃. The experiment shows that the frequency change from room temperature to turn point can reach 1.4×10^{-5}.

High precision OCXO used as phase locked oscillator does not need to put out accurate frequency signal directly, but to utilize the excellent specifications of the high precision OCXO based on the phase locked control. In the further experiment, we change the temperature by changing the bridge resistances in the temperature-control circuits of the SC cut OCXO. And the results are shown in Table 1.

TABLE I. THE STABILITY OF OCXO AT THE DIFFERENT BRIDGE RESISTANCES

Bridge resistance and Corresponding temperature	Frequency of OCXO (MHz)	Stability per second
4.5kΩ 85℃	10.0000232	5.3×10^{-12}
13.6kΩ 70℃	10.0000057	7.9×10^{-12}
19.8kΩ 55℃	9.9999771	1.3×10^{-11}
26.6kΩ 45℃	9.9999565	1.6×10^{-11}
29.8kΩ 35℃	9.9999318	2.3×10^{-11}

The frequency stability changes when the frequency of OCXO changes along with the temperature. The regulation of the constant temperature of the OCXO can improve its frequency deviation in a wide frequency range, and the stability per second is poorer than that at turn point. Further experiments show us when this OCXO is locked to another accurate and stable reference signal, the short-term stability is enhanced obviously. It is because that the phase lock overcomes the fluctuation of frequency shift aroused by temperature.

According to requirements, using this method the frequency can be locked and regulated in a wide range. Through the regulation of temperature, wide regulation range can be obtained, and the frequency of OCXO can be locked to the different output frequencies of HP8662A (principle diagram is shown in Fig.2). The results of the experiment are shown in Table 2.

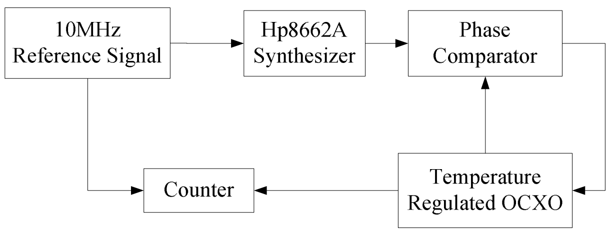

Figure2. A frequency locking experiment of a temperature regulating OCXO

TABLE II. THE FREQUENCY STABILITY OF LOCKED 10 MHZ OCXO BY HP8662A AT THE DIFFERENT BRIDGE RESISTANCES

HP8662A frequency	Bridge resistance of OCXO	Stability of OCXO (/s)
10.000005MHz	13.5KΩ	5.5×10^{-12}
9.999999MHz	15.6KΩ	5.4×10^{-12}
9.999985MHz	18.3KΩ	5.8×10^{-12}
9.999962MHz	22.9KΩ	6.0×10^{-12}
9.999950MHz	26.8KΩ	6.2×10^{-12}

From the table 2 we can see, when the bridge resistance changes, the frequency of OCXO changes obviously. When we lock it to the frequency of HP8662A, the frequency stability of OCXO almost does not change; here it is all at 10^{-12}. Therefore, although the method may affect the frequency stability when the frequency is not locked, but after it is locked, the influence is improved significantly. With the method the Q value of the OCXO is not affected. Its frequency is locked to host oscillator by phase controlled, the stability of this OCXO almost does not change after locked. So it meets the request for the accurate PLL.

The high-stability OCXO as a precision PLL can be locked by different frequency signal. Not only make sure the strictly correlativity of the frequency between OCXO and the host locking signal, but also make sure that the locked signal shows good frequency stability and phase noise specification. From the experiment we can see, the regulation range of high stability OCXO can be extended to 5×10^{-6} or wider, and the stability of the output signal is also 10^{-12} order as original.

In practical application, a variety of designs are possibly based on this principle. We can use simple frequency comparator based on a microprocessor or FPGA to judge the frequency of PLL OCXO and search the frequency – temperature data of OCXO in the microprocessor to change the bridge resistance. The frequency of the OCXO can be regulated to the range around expected value, and then the frequency can be locked to the requested frequency through phase-lock. Some circuits can share with the different systems.

III. HIGH PRECISION WIDE FREQUENCY-REGULATION OCXO APPROACH BASED ON TEMPERATURE CONTROL

The relationship between frequency of a high stable OCXO and controllable bridge resistance can be measured beforehand, and the relative data are stored into the memory of the microprocessor. The frequency of OCXO before locked is measured by simple device or analog approach, and the temperature of OCXO is changed by changing the resistance of a program-controlled potentiometer in it according to the measuring result. The frequency can be voltage-controlled to requested frequency, and then it will be locked by reference signal in a PLL. The principle diagram is shown in Fig.3.

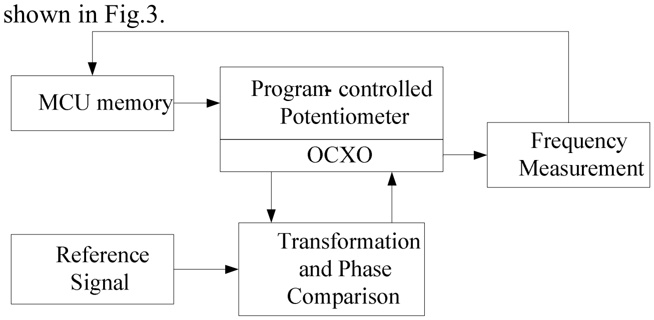

Figure3. The temperature – frequency control of OCXO

We have implemented several samples based on the principle above. The temperature frequency control can be implemented using different system hardware and part of software source. In this way, not only high precision phase lock is available in wide frequency range, but also good short-term stability, phase noise and aging specifications are guaranteed. Similar as the fundamental experiment above, the original short time stability, phase noise and aging per day are all remained, where aging is as high as 10^{-10}~10^{-12}. So, it is valuable to regulate the oscillator temperature control using overtone crystal oscillators for precision PLL purpose.

IV. CONCLUSION

This paper proposes a method to widen the frequency regulation range through temperature control of OCXO, and this method will not influence the frequency stability and aging of the OCXO. It is useful in the use of precision PLL oscillators and OCXO controlled in commercial atomic frequency standard.

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