A study on MEMS oscillators' frequency drift of temperature

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Abstract. The frequency output of oscillators is subject to a series of factors, such as working temperature, humidity, shock and vibration. Most of these factors are related to the manufacturing processes and packaging techniques employed in the semiconductor industry. Among the above factors, the influence of temperature is the most direct and most significant. And the effect of temperature on the frequency output of the oscillator is also called oscillators' frequency drift of temperature. This project aims to study frequency drift of two types of oscillators influenced by temperature, namely Quarts oscillators and MEMS oscillators. Firstly, the report states two types of oscillators' strength and weakness respectively. And then, referring to some industrial standards, the report also deceives and performs a series of tests to obtain data about the behavior of oscillators in different temperature. The experimental results show that the curve of the frequency-temperature of OCXO is approximately a horizontal line. And the curve of MEMS oscillator 1 looks like a capital letter M with relative small amplitude, and the curve of MEMS oscillator 2 is close to a slowly decreasing line. While the curve of crystal oscillator is a sine curve with steep rise at the end. According to the diagram, a conclusion that MEMS oscillators' frequency drift of temperature is less than that of crystal oscillators can be drawn naturally.

1 Introduction

Micro-Electro-Mechanical System (MEMS) can be traced back to 1970s. It is an independent smart and complete system with the micro size ranging from 20um to 1mm [1]. Depending on the different design functions, they have vastly different internal structures. Some are so simple that with no movement component in the inner structure. Others, however, have quite complex electromechanical systems as well as quantities of moving components controlled by integrated microelectronics.

When MEMS system was first introduced, the application field was limited a lot due to the immature manufacturing process and research. But as technology advances, its application has penetrated into many fields. Up to now, there are various MEMS devices designed for certain functions in the market. For example, MEMS are used to improve current medical technologies, such as surgical scalpel, making surgeons perform delicate

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surgical procedures more precisely. And they are used in smart phones, such as a variety of smaller sensors, which make the smart phones more and more powerful and smaller. Another promising area of MEMS device applications is the field of oscillators.

2 MEMS oscillators vs quartz oscillators

MEMS oscillators and quartz oscillators play a dominated role in oscillator market nowadays. At the beginning, the report will state the strength and weakness of the two types of oscillators severally, in terms of physical dimensions, costs, performance as well as manufacturing and packaging techniques.

Quartz oscillators, as we all known, were widely used for decades, during which quantities of research on quartz technology had been conducted. Thus, Quartz oscillators had huge advantages over MEMS oscillators which were new born. For instance, Quartz oscillators enjoyed great reputation for lower cost of production, more excellent stability and higher quality of frequency output. In contrast, not only did MEMS oscillators leave much desire for the performance on the circumstance of jitter and phase noise, but also are limited to a narrower frequency range [2]. On the other hand, Quartz oscillators have apparent shortcomings compared with MEMS Oscillators. The size of Quartz oscillators which are 10 times than that of MEMS oscillators is so big that it prevents Quartz oscillators from widely usage in electronic production fabricated smaller and smaller. Instead, MEMS oscillators with micro size are preferable to the electronic production market [3]. What is the most important is that cost reduces sharply to a affordable level with the development of the science of material and the advance of manufacturing process [4]. In addition, MEMS oscillators can provide several different Radio Frequencies in one die rather than only one kind of frequency providing by one quartz oscillator. Another breakthrough is a new vacuum sealing wafer level packaging technology developed by SII collaborated with IME [5, 6]. The new technology costs less, consumes less power and leads to stronger mechanical strength. However, the quality of performance of MEMS oscillators cannot match up with that of quartz oscillators, which is a hard nut to crack for the scientists and researchers to substitute MEMS oscillators for quartz oscillators.

3 Device under test

At the present time, high-accuracy applications such as servers and routers have higher demands for timing or timing devices. Besides, as the development of science and technology, higher frequencies (more than 50MHz), better signal purity and greater reliability are of much more significance. Traditional quartz oscillators, however, cannot satisfy the demands mentioned above. On the contrary, MEMS oscillators can make it. Apart from influence factors brought about in manufacturing and processing, the most important factor leading to the deviation from expected value is temperature. Scientists and engineers have done a lot to improve quartz oscillators' temperature stability, such as temperature compensation [7]. In this test, four samples (a frequency specification of 100MHz) including one OCXO (Oven-Controlled Crystal Oscillator), one common crystal oscillator and two MEMS oscillators(MEMS Oscillator 1 and MEMS Oscillator 2) produced by different manufactures are chosen to carry out the experiment to explore the MEMS oscillator's frequency drift of temperature. It is worth mentioning that the two MEMS oscillators presented above are mainstream products in the market. And the detailed information of the samples are shown in the table 1.

Table 1. Some information of the samples chosen in the experiment.

Number of Samples	Picture	Size(mm)
Samples 1 (OCXO)		25.4 x 25.4 x 13.5
Samples 2 (MEMS oscillator 1)		3.2 x 2.5 x 0.85
Samples 3 (MEMS oscillator 2)		3.2 x 2.5 x 0.85
Samples 4 (Crystal oscillator)		3.2 x 2.5 x 0.85

4 Design of experiment and test device

Fig. 1. Diagram of test device with one multiplexer.
In order to complete the study of the subject, the article referred to some literature and related industrial standards. And the various internationally-approved test standards were

studied in detail. Finally, taking the nature of our equipment and limiting factors like time constraint into account, we came up with the experiment. Therefore the tests conducted in this project are customized for the scope and specifications of this project and the results should be used as references and not definite conclusions.

The devices used in the test are shown in figure 1. In case of distortion in the process of frequency signal transmission, test board, amplifier and multiplexer involved in this test were chosen cautiously. Pre experiments also proved that devices adopted were suitable.

4.1 Short term temperature stability test (STT)

The implementation of the STT is to figure out whether the frequency of the oscillators can be kept constant at different temperatures. Figure 2 illustrates the way the test is conducted. Samples in the thermal chamber firstly are cooled to -42.5°C also called Lower Soak Temperature (LST) in 17 minutes and maintained for another 15 minutes in LST. Then they are warmed up by 2.5°C in 2 minutes every time and a soak time of 15 minutes at that constant temperature until the value of temperature reach 92.5°C also named Upper Soak Temperature (UST). After that a similar process will be conducted to cool the temperature to LST, which is a complete cycle controlled by LabVIEW program. The diagram below illustrates detailed information of the process.

Fig. 2. Schematic diagram of STT.

5 Data analyzing

Fig. 3. One-Cycle Frequency-Temperature Curve of STT.

According to the figure 3 given above, when temperature in the thermal chamber rising step by step from -42.5°C to 92.5°C and return to -42.5°C in the same way, the frequency-temperature curve of MEMS oscillator 1 appears in the shape of uppercase letter M ranging from 99998000Hz to 100001000Hz , and the curve of MEMS oscillator 2 is approximately a downward line varying from 100MHz to 100001500Hz . When it comes to the curve of OCXO, it approximately presents as a horizontal line at nearly 100000200Hz . At last, the profile of the crystal oscillator looks similar to a single period of a sine curve with the right end of the curve extending upwards. To sum up, the frequency produced by the MEMS oscillator is more stable than that of the crystal oscillator but cannot compare to that of OCXO varied in temperature.

6 Conclusion

As discussed above, the temperature drift of MEMS oscillators is not in the least inferior to that of traditional crystal oscillators and some even better, but less than OCXO's. Moreover, with the development of technology, MEMS oscillators show sharp advantages over traditional crystal oscillators of size, cost, and mechanical strength. Above all, MEMS oscillators show better performance as they have less deviation with the change in temperature. If crystal oscillators in the ovens are placed by MEMS oscillators, the Oven Controlled MEMS oscillators can also have great stability as OCXO do. It can be foreseen that with the further progress of MEMS technology, MEMS oscillators will show more prominent advantages in the trend of intellectualization and miniaturization of electronic products, and even completely replace the traditional crystal oscillator.

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