System Advantages with Epoch Platform MEMS OCXOs

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1. Introduction

With the rapid growth of network infrastructure and the convergence of 5G and datacenters, the timing specifications for high-stability and low-latency solutions have become increasingly stringent. Traditional OCXOs face limitations in size and performance, posing challenges for engineers. However, the Epoch Platform™ MEMS OCXOs (SiT5801, SiT5802, SiT5811, SiT5812) address these barriers by combining MEMS technology and a unique thermal structure, offering unprecedented stability and accuracy in a compact 9.0 mm x 7.0 mm x 3.6 mm package.

This paper highlights the advantages of the Epoch Platform over quartz OCXOs in various features. By leveraging the benefits of MEMS technology, this new generation of OCXOs offers optimized performance, making it an ideal choice for applications where power efficiency, system miniaturization, and resiliency are crucial.

2. Design Benefits

The rapid evolution of network technology has necessitated advanced solutions to meet increasing demands for stability and performance. This section presents the innovative Epoch Platform MEMS OCXOs that combine the advantages of both traditional quartz OCXOs and miniaturized ASIC OCXOs. The Epoch Platform OCXOs deliver high frequency stability and accuracy, even in constrained spaces and harsh environments.

The Epoch Platform OCXOs offer several advantages over traditional OCXO technology for system designers. They utilize SiTime's patented silicon MEMS and mixed-signal IC technologies to create a highly reliable and stable oscillator, in addition to RF-grade phase noise and low vibration sensitivity. This allows the Epoch Platform to maintain high stability even under mechanical and thermal stress, making it suitable for harsh environmental conditions. The Epoch Platform's DualMEMS® design enables it to easily adapt to different applications and environments, unaffected by changes in temperature or the presence of airflow. It also minimizes the impact of solder-down shift, surpassing the limitations of traditional OCXO power cycles. It can withstand 10 times more power cycles than traditional quartz OCXOs, a testament to its highly durable and reliable design. By utilizing the Epoch Platform OCXOs, system designers can overcome the limitations of traditional OCXOs and create higher performing and more reliable systems.

2.1. Solder-Down Shift

Solder-down shift occurs due to material changes caused by high-temperature stress during soldering. Stress-related interactions play a critical role in the solder-down process. However, while creating a robust electrical connection between components, the soldering process can introduce thermal and mechanical stress. This stress can cause the clock frequency to deviate during reflow, a phenomenon known as solder-down shift. Solder-down shift can result in material changes that degrade device performance and cause clock stability violations in the many networking applications that have strict lifetime synchronization and delay requirements.

With the Epoch Platform, SiTime has optimized the oscillator structure to overcome the frequency changes caused by thermal and mechanical stress during the reflow process. This optimization ensures that the frequency remains precise after the manufacturing process. The Epoch Platform demonstrates a frequency deviation of less than 5 ppb after two reflows (Figure 2-1).

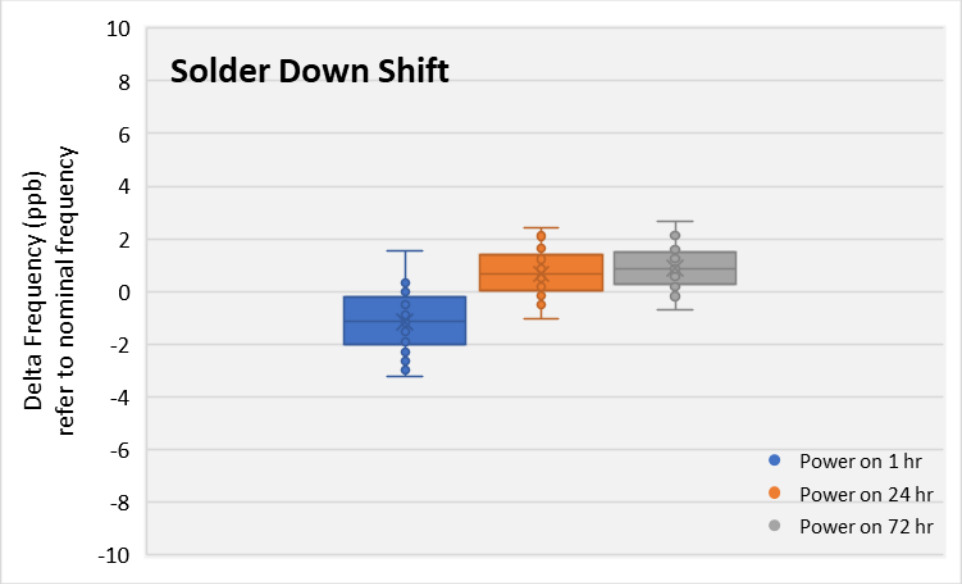

Figure 2-1: Frequency Deviation after 2 times Reflow Process

2.2. Power on and Retrace

The Epoch Platform offers a significant advantage over traditional OCXOs with its miniaturized design, resulting in a much shorter warmup time for stabilization, due to its small thermal mass. Because of its fast-responding thermal control loop, the Epoch Platform demonstrates an impressive warm-up characteristic, reaching stability of ±1 ppb in less than 1 minute.

Another critical feature in OCXO performance is retrace, which occurs when the supply power is cut off and reapplied after a defined period. During this process, thermal stresses from the heating and cooling of the oven structure can cause the frequency to return to a different value than it was before being powered off. The Epoch Platform leverages precise semiconductor process control to minimize the impact of stress-induced effects.

Figure 2-2 showcases the low retrace of the Epoch Platform. After 24 hours of powered off, the frequency deviates by less than 1 ppb when powered back on. This outstanding accuracy makes the Epoch Platform an ideal choice for applications requiring consistent and reliable performance even after long power interruptions.

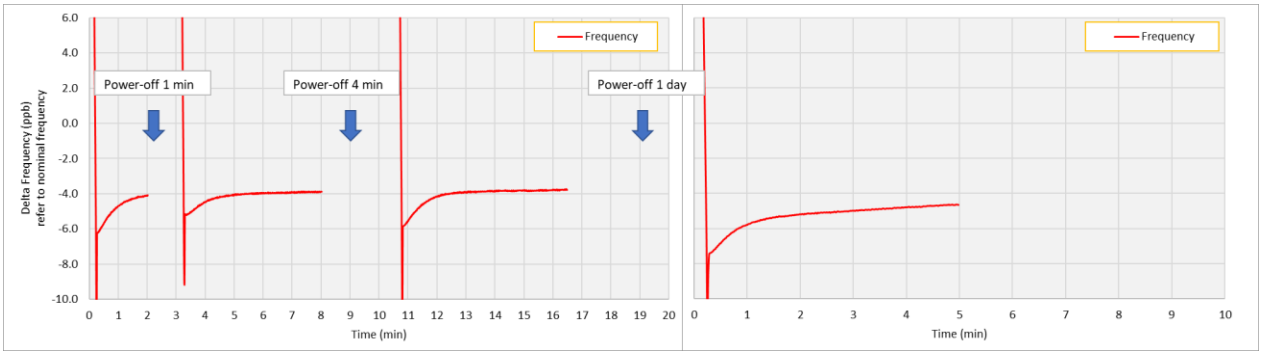

Figure 2-2: Power on and Retrace Characteristic

2.3. Hysteresis and Temperature Slope

During system operation, temperature changes can significantly impact performance. Thus, it is crucial to consider temperature stability and dynamic indices like frequency slope (dF/dT) during the early design stage.

In 2017 SiTime introduced a new temperature sensor technology featuring a dual-microelectromechanical system (MEMS) resonator. [1] The advanced DualMEMS temperature sensor architecture provides low-noise digital characteristics and high-bandwidth temperature-to-digital converters (TDC) enabled by advanced CMOS technology. This combination allows the sensor to compensate for fast temperature changes effectively.

The Epoch Platform is designed to perform reliably in a wide operating temperature range from -40°C to 95°C, ensuring ±1 ppb stability regardless of how fast the temperature changes occur, and offering a stability over temperature slope (dF/dT) of ±0.01 ppb/°C. This means it can accurately track and adjust for temperature variations, providing precise and consistent performance, as demonstrated in Figure 2-3 and Figure 2-4.

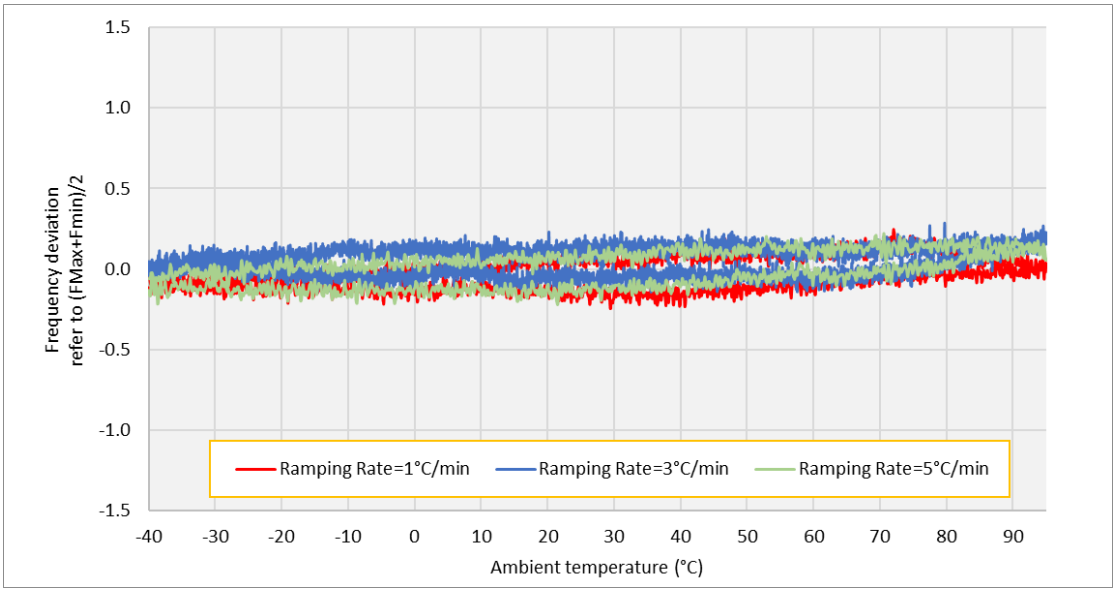

Figure 2-3: Epoch Platform Stability over Temperature

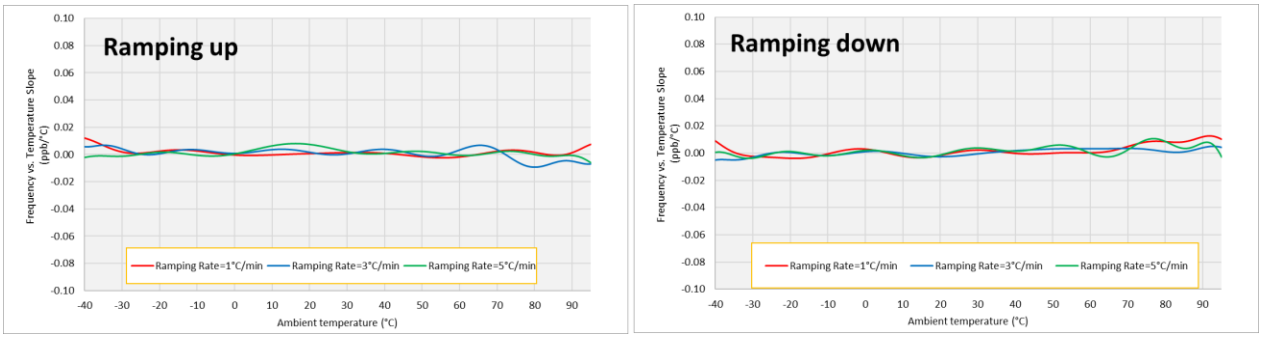

Figure 2-4: Epoch Platform Stability over Temperature Slope (dF/dT)

2.4. Resistance to Airflow

Ensuring device stability is a primary concern for traditional OCXO vendors, who often recommend positioning the device far away from fans or add covers to maintain oven stability and reduce thermal loss. However, such measures can lead to layout challenges, especially in constrained system size applications.

In contrast, the Epoch Platform sets itself apart with its innovative design, featuring DualMEMS temperature sensors and a robust thermal architecture that is resistant to rapid airflow. This unique design enables the Epoch Platform to maintain high accuracy as a clock source, even in the presence of varying airflow conditions. Figure 2-5 shows the output frequency of the Epoch Platform in ppb as a 3 m/s of airflow, flowing over the device, is periodically turned on and off. Traditional OCXOs will have frequency perturbations of several ppb or more under airflow. In contrast, the Epoch Platform OCXOs show minimal frequency disturbance, leading to excellent holdover under airflow (Figure 2-6).

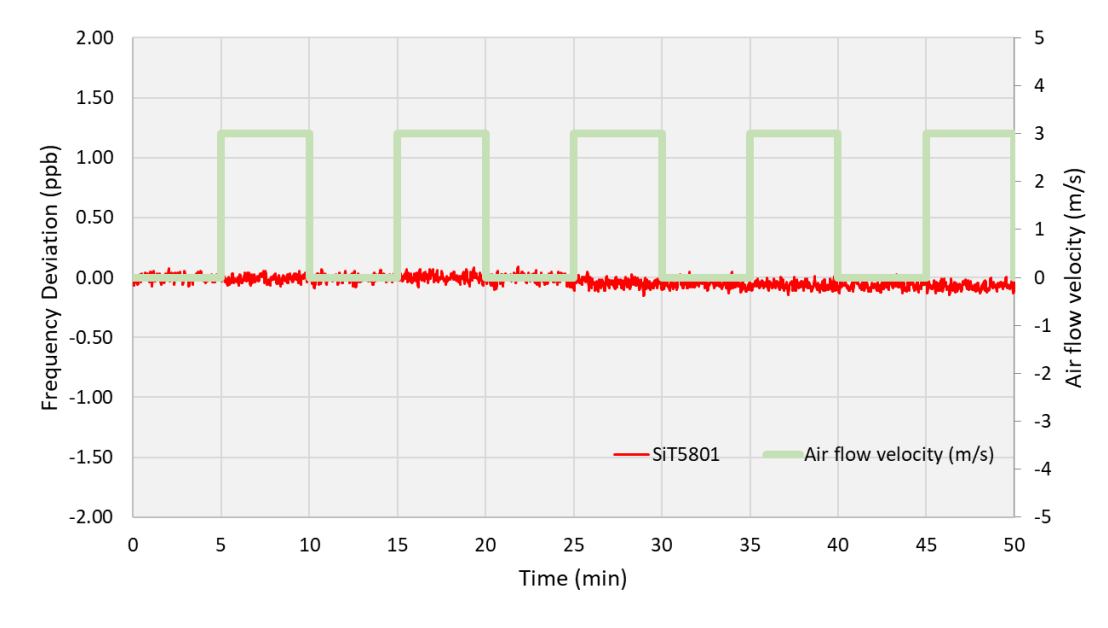

Figure 2-5: Frequency Deviation Under Changing Airflow

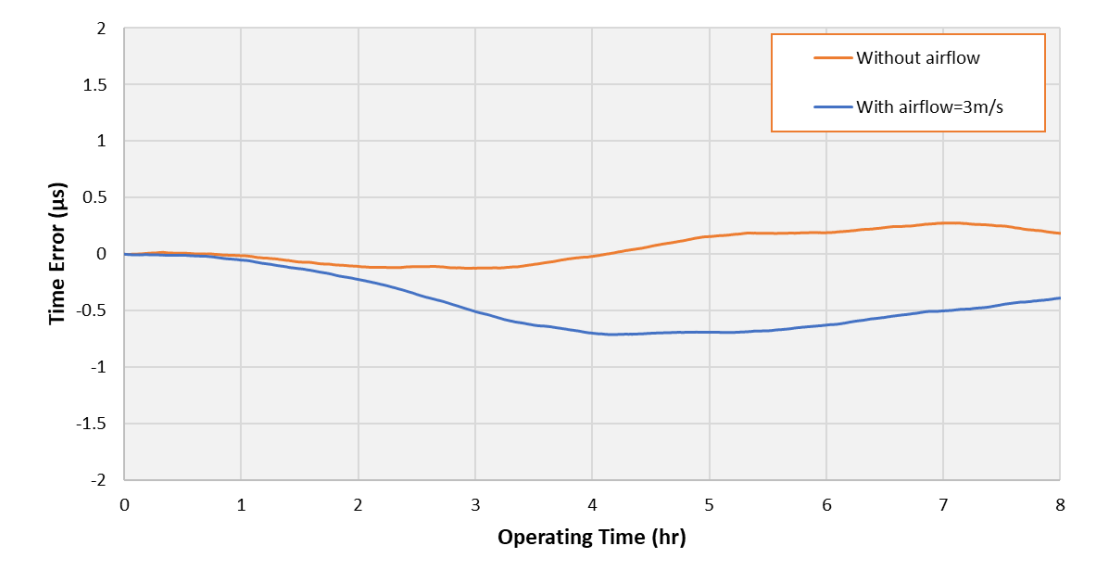

Figure 2-6: Holdover with and without Airflow

2.5. Supply Voltage Variation

When the supply voltage to an OCXO fluctuates, it can lead to variations in the oscillation or thermal control circuit, resulting in instantaneous deviations in the output frequency and therefore time error. The Epoch Platform integrates on-chip power supply noise filtering to address this critical issue, providing unparalleled frequency stability even under unstable power module conditions, as shown in Figure 2-7.

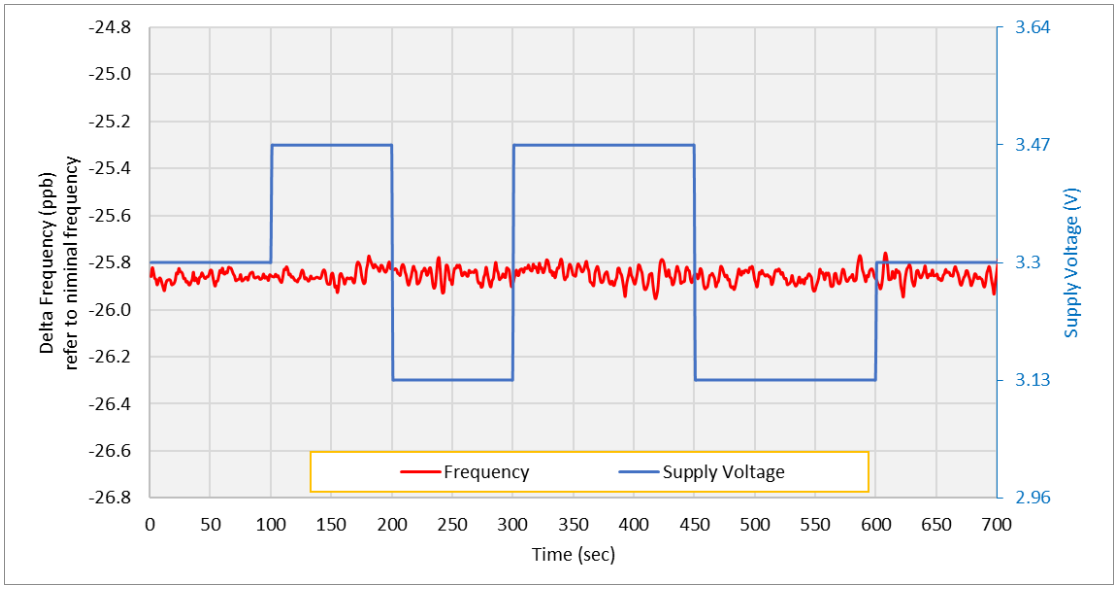

Figure 2-7: Frequency Stability under Supply Voltage Variation

The on-chip power supply noise filtering capability of Epoch Platform ensures consistent and precise frequency synchronization, irrespective of layout space limitations or the placement of Low Drop-Out (LDO) regulators.

3. Conclusion

As is evident from the preceding discussion, the unique design of the Epoch Platform results in many system design advantages. Solder down shift is much smaller when compared to legacy quartz devices. The Epoch Platform power up and retrace times are very small and also very predictable from device to device. Hysteresis is on the order of ±0.1 ppb and dF/dT, or the slope of the frequency vs temperature curve, is very consistent and an order of magnitude smaller than competitive quartz devices. Finally, airflow and power supply variations show no impact on the output frequency. These component level advantages will combine to achieve, for example, lower time error in holdover and dynamic TDEV in a IEEE 1588 loop. The Epoch Platform represents a new benchmark for OCXO performance and ease of use for system designers.

4. References

[1] M. H. Roshan et al., "A MEMS-assisted temperature sensor with 20- µK resolution, conversion rate of 200 S/s, and FOM of 0.04 pJK2," J. Solid-State Circuits, vol. 52, no. 1, pp. 185–197, Jan. 2017.

Table 1: Revision History

Version	Release Date	Change Summary
1.0	19-Sep-2023	Initial Release

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