TCXO Frequency Stability and Frequency Accuracy Budget

1 Introduction

Temperature compensated oscillators (TCXOs) are used for frequency reference in systems that typically require frequency stability of 5 ppm or better. The frequency accuracy in these systems must, in general, be maintained within a timing budget that takes into account frequency drift of the TCXO due to all factors including variations in operating temperature, supply voltage, output load, and aging during the entire system operating lifetime. A set of frequency stability parameters is commonly defined by the industry to quantify the influence of environmental factors and circuit conditions on reference oscillators. This document explains the frequency stability specifications in SiTime TCXO datasheets and how the limits of frequency accuracy are calculated.

2 Temperature stability and frequency accuracy

SiTime TCXO datasheets includes the following frequency stability specifications:

Initial tolerance (F_init) is frequency deviation from nominal frequency at room temperature, e.g. 25±3°C. It is measured under typical power supply voltage and output load conditions with the device mounted on a printed circuit board (PCB). The main components of the initial tolerance are residual frequency error after temperature calibration at the SiTime factory and frequency shift due to PCB soldering.

The contribution of initial tolerance to the system timing budget can be minimized by using voltage-controlled TCXO (VCTCXO) and frequency calibration after the PCB reflow assembly process.

Stability over temperature (F_stab) characterizes the frequency drift caused by ambient temperature change and is specified as one-half of the peak-to-peak frequency deviation over the full operating temperature range.

Stability over supply voltage (F_vdd) specifies the frequency shift caused by a power supply voltage change within ±10% for 2.5V to 3.3V VDD or ±5% for 1.8V VDD.

Stability over output load (F_load) specifies the frequency shift caused by the difference in loading capacitance on the output pin, up to 15 pF for LVCMOS output oscillators.

Overall frequency accuracy (F_total) is calculated as sum of all the above parameters. For example, the overall frequency accuracy of a SiT5000 VCTCXO with ±2.5 ppm temperature stability is: F_total = F_init + F_stab + F_vdd + F_load = 1 + 2.5 + 0.05 + 0.1 = 3.65 ppm.

Better overall frequency accuracy can be achieved by using the VCTCXO option to reduce initial tolerance by system calibration: F_total = F_stab + F_vdd + F_load = 2.5 + 0.05 + 0.1 = 2.65 ppm.

Temperature stability is usually the dominate source of frequency error in applications using a TXCO. Unlike frequency offset at room temperature, temperature drift cannot be canceled out by using a simple calibration scheme.

3 Aging and frequency accuracy

Even under constant operating conditions, TCXO frequency can shift over time due to internal changes within the device. An additional parameter for frequency shift over time is required in the system budget. The most commonly used parameters are first year aging and 10-year aging.

First year aging specifies the limit of frequency shift, with respect to initial frequency, after one year of continuous operation under constant power supply voltage and operating temperature, typically at 25°C.

10-year aging specifies the limit of frequency shift, with respect to initial frequency, after 10 years of continuous operation at constant operating conditions. 10-year aging specifications are extrapolated numbers from frequency measurements performed on a statistically significant set of samples over 9 to 18 months or even longer period of time.

To calculate overall frequency accuracy including 1-year or 10-year aging: F_total = F_init + F_stab + F_vdd + F_load + F_aging.

For example, the first year aging of a SiT5000 2.5 ppm VCTCXO is ±1.5 ppm. The overall frequency accuracy can then be calculated as: F_total = F_init + F_stab + F_vdd + F_load _ F_aging = 1 + 2.5 + 0.05 + 0.1 + 1.5 = 5.15 ppm. The 10-year aging for the same VCTCXO is ±3.5 ppm, which results in an overall frequency accuracy of ±7.15 ppm over ten years.

Using the same voltage tuning option for TCXO devices and system calibration can enable tighter limits in the frequency accuracy budget. For example, removing initial tolerance after PCB assembly and correcting aging related frequency shift periodically over the product lifetime will increases accuracy.

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