kHz-band DTCXO timekeeping accuracy in a temperature changing environment

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Overview

Epson has a lineup of RTC modules and kHz-band oscillators that have a built-in digital temperature compensation crystal oscillator (DTCXO*). This paper describes this feature that allows time sleeping accuracy over dramatic temperature swings may be significantly improved with DTCXO technology. We performed actual tests of the DTCXO in a vehicle and verified the performance. The cumulative time error was 46 seconds in a period of 2 years and 5 months, which is equivalent to 1.6 seconds per month.

*DTCXO: Digital Temperature Compensated Xtal Oscillator

Frequency/temperature characteristics before and after temperature compensation

Figure 1 shows the frequency/temperature characteristics of a tuning fork crystal unit used in kHz-band oscillation. This tuning-fork crystal unit has strong secondary frequency/temperature characteristics. Figure 2 shows actual measurements of frequency/temperature characteristics after temperature compensation with a DTCXO. There is a number improvement in frequency tolerance compared to before compensation.

Figure 1. Tuning fork crystal unit frequency/temperature characteristics

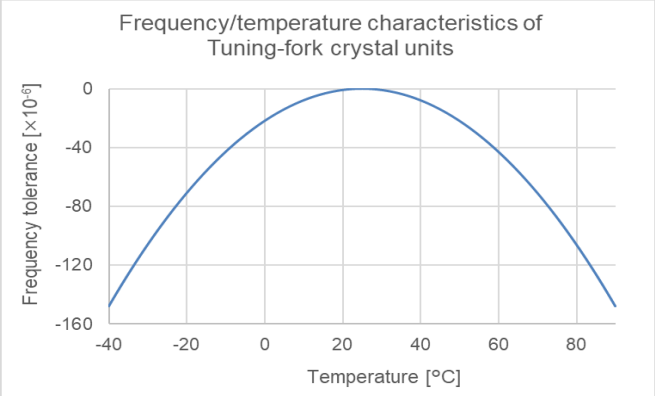
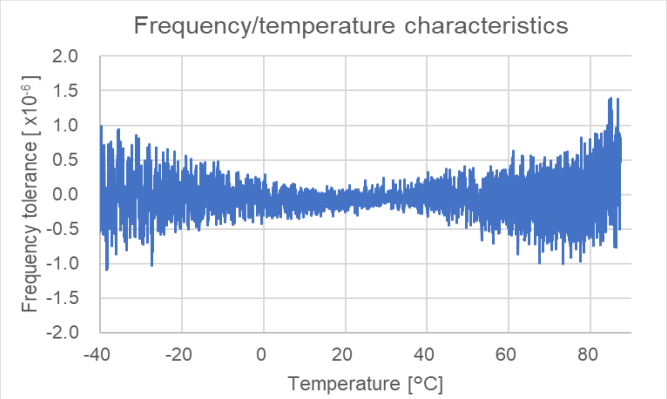


Figure 2. Actual measurements of DTCXO frequency/temperature characteristics



kHz-band DTCXO frequency compensation method

Figure 3. kHz-band DTCXO frequency compensation block

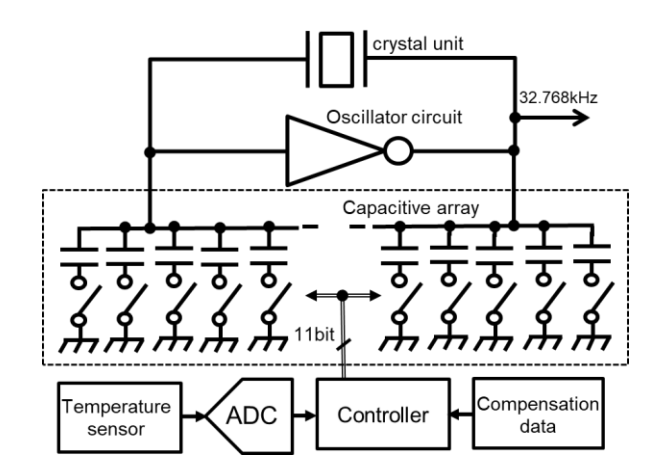


Figure 3 shows the kHz-band DTCXO frequency compensation block that Epson uses.
The frequency is compensated so that it exhibits a flat characteristic by varying, depending on the temperature, the number of capacitive arrays connected to the oscillator. The capacitance value is adjusted in 2,048 ways using an 11-bit digital signal that turns the capacitor connection on/off. In Epson's kHz-band DTCXO, temperature is detected at a resolution of about 0.3 °C by a temperature sensor and ADC. Afterwards, the corresponding capacitor is connected, and the frequency is compensated. A frequency gap generated by capacitance switching results in error, and the frequency tolerance goes up and down in small increments depending on the temperature as shown in Fig. 2. The is a characteristic of DTCXO temperature compensation.

Results of kHz-band DTCXO timekeeping accuracy measurements

This kHz-band DTCXO was operated continuously for 2 years and 5 months in the field. The timekeeping accuracy results are shown here. The graph in Figure 4 shows measurements of the temperature environment taken by a data logger. Two types environment test conditions were performed, one in the rear seat of a vehicle (about 20 °C/day, from 0 to 11 months in Fig5) and the other in the dashboard (about 80 °C/day, from 11 to 29 months in Fig5).

Figure 4. Measured time temperature characteristics

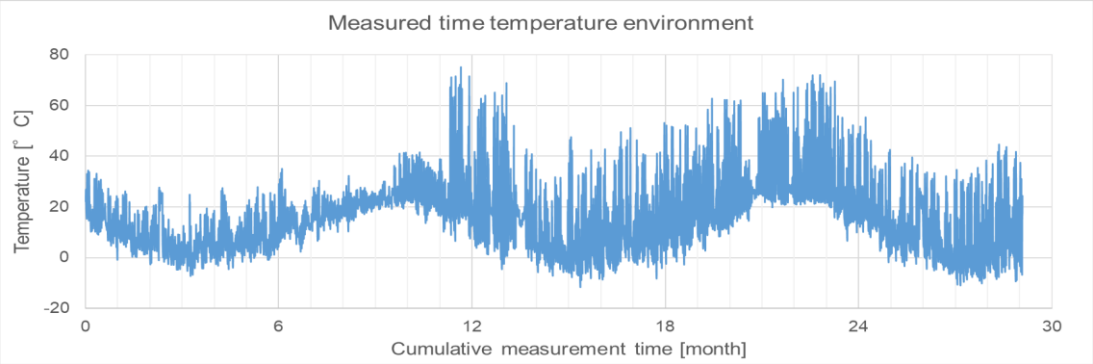


Figure 5. Cumulative time error of a kHz-band DTCXO

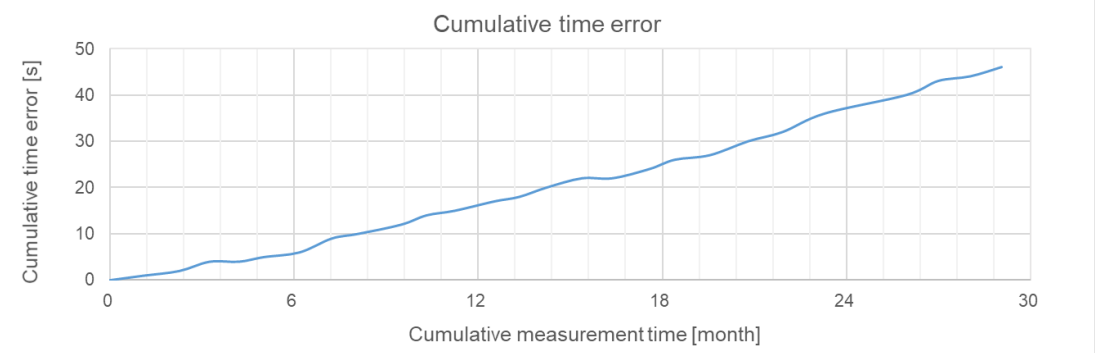


Figure 5 shows the cumulative time error under actual usage conditions. The cumulative time error was 46 seconds in a period of 2 years and 5 months, which is equivalent to 1.6 seconds per month.
It can be seen that the time change is small and stable even when there are sharp temperature changes during a day, as well as when temperature changes are gradual and over a long period of time as the seasons change. This is because the frequency/temperature tolerance of a kHz-band DTCXO changes up and down in small increments, so if the temperature changes continuously, it will be averaged and the cumulative time error will decrease. A kHz-band DTCXO is an excellent device that can provide exceptionally accurate time information.

Please consider using oscillators and RTC module equipped with an Epson kHz-band DTCXO for equipment that requires high-accuracy time information in environments subject to temperature changes.

Reference: The Epson products listed below are equipped with a kHz-band DTCXO. (Information current as of November 2021.)

RTC modules

Industrial applications: RX8901CE, RX4901CE, RX8804CE, RX8900CE, RX-8803LC, RX-4803LC, RX8900SA, RX-8803SA, RX-4803SA

Vehicle applications: RA8000CE, RA4000CE, RA8804CE, RA8900CE, RA8803SA, RA4803SA

32.768 kHz oscillators

Industrial applications: TG-3541CE Vehicle applications: TG-3541CEA