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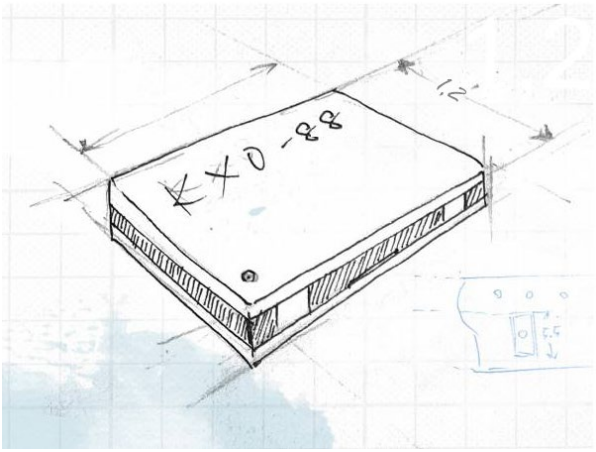
Setting the pace with TCXO - Small, precise, reliable

Development of the demand for TCXOs (Temperature Compensated Crystal Oscillators) and the advantages this type of oscillator brings with it.

ABSTRACT

The trend towards miniaturization with increasingly demanding technical parameters is becoming more and more noticeable in the TCXO sector.
Along with the explosive development of 5G networks and the automotive industry, the IoT sector, mobile communication technology, medical technology also demand high precision. TCXO was already the best-selling oscillator type in 2019, and the market forecasts were very good. However, due to the recent crisis years, development in some areas was very subdued and priorities were re-set. The significant recovery in this oscillator segment, is supported by manufacturers with extremely performant components.



BASICS

In the following, we summarize the principle of the oscillators according to the latest state of the art. The changes that constitute the progress are mainly related to frequency stability, phase noise and power consumption.
The following 3 groups of quartz oscillators differ in the measures they take for temperature compensation:

- **XO, Crystal Oscillator - a** crystal oscillator without special measures for temperature compensation. Its temperature behaviour is the same as that of the crystal used.
- **TCXO, Temperature Compensated Crystal Oscillator - a** temperature compensated crystal oscillator, in which a correction voltage is generated by temperature dependent resistors or similar, used for frequency correction. Analogue TCXOs can achieve about 20 times improvement over crystals alone.
- **OCXO, Oven Controlled Crystal Oscillator - a** thermostatically controlled crystal oscillator in which the crystal and other temperature-sensitive parts are in a chamber where the temperature is selected so that the crystal no longer has any appreciable temperature response. OCXOs can achieve more than 1000 times improvement over quartz alone.

An extended temperature range XO typically has a frequency stability of about 10-50 ppm over the entire temperature range. A TCXO can typically reduce that to about 0.5-1 ppm. An OCXO can undercut that to 0.01 ppm, but with the disadvantage of much higher power consumption.

Recently there are also special TCXOs on the market, e.g. for aerospace technology, with significantly better frequency stability and extended temperature ranges, but these are highly expensive and therefore not economically viable for all applications.

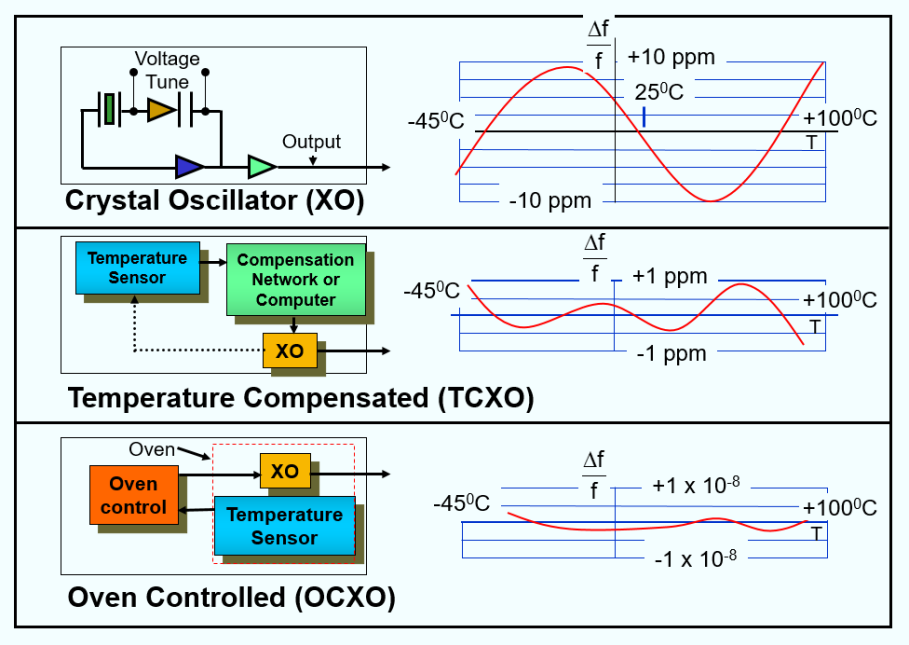


Fig. 1: Principle and frequency deviation of the most important oscillator types

If additional voltage control is required, a **VCTCXO (Voltage Controlled Temperature Compensated Oscillator)** is used. In this case, the frequency is changed (pulled) within certain limits (pulling range - usually a few tens of ppm) by means of a control voltage (V_c).

The graph in Fig. 2 shows the correction voltage supplied to the oscillator to minimize the deviation over the temperature range.

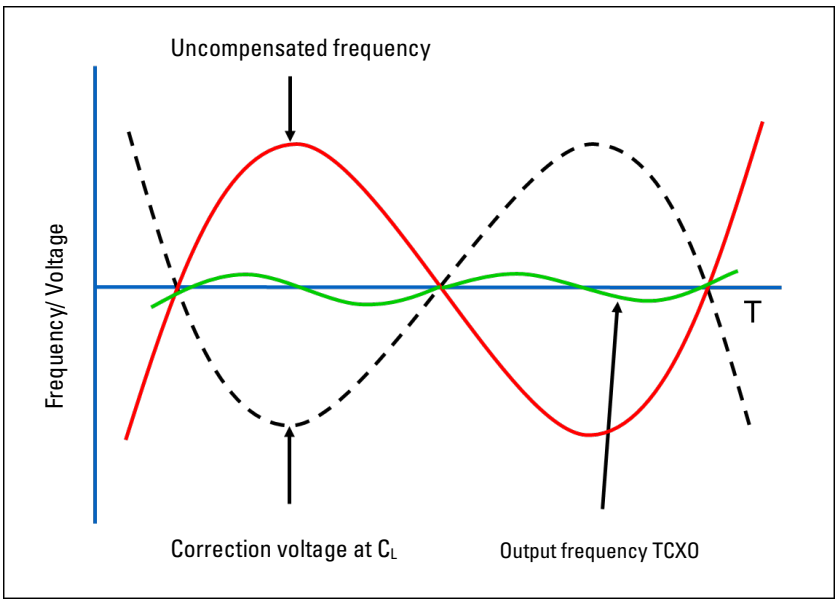


Fig. 2: Control principle of the TCXO

The most important criteria for oscillator selection are:

- Signal output
- Frequency accuracy or stability
- Environmental conditions, e.g. temperature, shock, etc.
- Power consumption
- Phase noise
- Size
- Cost

While the common oscillators have mainly HCMOS or TTL outputs, the TCXOs are manufactured with Sine or HCMOS outputs. These differ essentially by:

Sine wave output = Clipped sine wave (CSW)

- among other things, lower power consumption
- slightly less phase noise
- better EMC due to less harmonics

HCMOS output

- Defined switching edges
- Adjusted levels for the corresponding logic families (L<0.1 V_{DD}; H>0.9 V_{DD})

Crystal oscillators do not have any failure mechanisms based on principle. They usually operate within specification for years. When a crystal oscillator fails, it is for reasons such as:

- Poor solder joints
- Loss of vacuum due to mechanical influence
- "Drifting away" of the temperature compensation when operating out of specification
- Nuclear radiation
- Shock and/or vibration

An overview of the most common oscillator types with standard parameters can be found in the table below. The values are only exemplary. They are manufacturer and type dependent.

	XOs	VCXOs	TCXOs	VCTCXOs
Case type	1.6x1.2 mm to 7.0x5.0 mm	3.2x2.5 mm to 7.0x5.0 mm	1.6x1.2 mm to 7.0x5.0 mm	2.0x1.6 mm to 7.0x5.0 mm
Oscillator Output	HCMOS + LVDS	HCMOS + LVDS	HCMOS + Clipped Sinewave	
Frequency range	1.0–200.0 MHz (10.0-800 MHz LVDS)	1.0-170.0 MHz (20.0-700 MHz LVDS)	6-60 MHz	
Frequency stability (typ.)	±25 ppm @ -20°~+70°C ±25 ppm; ±50 ppm @ -40°~+85°C		±0.5 ~ 2.5 ppm @-40°~+85°C (depending on type)	

Table 1: Oscillator types in comparison

DEMANDING APPLICATIONS AND TRENDS

While the oscillator market suffered a slump in accordance with the general economic situation during the pandemic years, it has since recovered and, according to analysts, points to a significant increase in the next 5 years. Thus, the original growth trend of 2019 will be continued and exceeded.

TCXOs are increasingly resonating with individual industries, both commercial, defense, industrial and medical.
Any circuit for an application that requires a precise and stable timing reference can theoretically be built with a TCXO.

In the manufacturing of the TCXOs, great emphasis is placed on highly finished quartz blanks (quartz wafers) and the corresponding circuit electronics to minimize phase noise and power consumption. These 2 parameters, together with the frequency stability, significantly determine the technical performance of the oscillator and thus indirectly the application range.

The evolution of 5G networks, aerospace and defense industries significantly determine the development of the special TCXOs with a frequency stability of about 10 ppb over an extended temperature range of -40 to +105°C.

The consumer sector, the automation sector and, increasingly, the medical technology sector are turning to the more common TCXOs, where the trend towards miniaturization with ever-better frequency behaviour is clearly noticeable.

The table provides a simple overview of today's most common requirements and trends regarding frequency precision and package type in the respective areas. These are guideline values which are more or less stringent from case to case. The quality of a TCXO is, as already described, determined by many more parameters, which can be found in detail on the homepages of the individual manufacturers.

Application	Frequency stability	Case type
Telecommunication	±0.5 ~ 2.5 ppm @-40°~+85°C	3.2x2.5 mm
Industry Automation	±1.5 ~ 2.0 ppm @-30°~+85°C	3.2x2.5 mm 2.5x2.0 mm
Medical Devices	±0.5 ~ 2.0 ppm @-30°~+85°C	2.5x2.0 mm 2.0x1.6 mm 1.6x1.2 mm
IIoT	±0.5 ~ 1.5 ppm @-30°~+85°C	2.0x1.6 mm 1.6x1.2 mm
5G networks, high bit rate & low latency networks, IEEE15588 BC and TC	Stratum3 konforme Stabilität <±0.4 ppm	7.0x5.0 mm 5.0x3.2 mm
Automotive	±2.5 ~ 5.0 ppm @-40°~+105°C	2.5x2.0 mm 2.0x1.6 mm
Aeronautics and aerospace	±10 ppb @-40°~+105°C	7.0x5.0 mm
Defence Technology	±10 ppb @-40°~+105°C	7.0x5.0 mm

Table 2: Applications for TCXOs and the most common frequency stabilities

OUR PRODUCTS FOR THIS PUROPOSE

As a long-standing manufacturer of crystals and oscillators, we at GEYER Quartz Technology always keep up with the times.

With our products we follow the latest market requirements and always offer our customers the possibility to create their designs for the high precision applications in mobile communication technology, the IOT sector, medical technology, amongst others, with TCXOs of the latest generation.

Reliable signal transmission, excellent frequency accuracy and low power consumption are just some of the parameters offered by our TCXO family. The list of complete parameters can be found on the GEYER Electronic homepage: https://www.geyer-electronic.de/en/products/oscillators/#32b260b7a45f0b4f9

	KXO-84	KXO-86	KXO-81	KXO-88
Case type	3.2x2.5 mm	2.5x2.0 mm	2.0x1.6 mm	1.6x1.2 mm
Oscillator Output	HCMOS Clipped Sinewave	HCMOS Clipped Sinewave	HCMOS Clipped Sinewave	Clipped Sinewave
Frequency range	8.0–70.0 MHz	13.0-56.0 MHz	9.5-60 MHz	13.0-52 MHz
Frequency stability (typ.)	±0.5 ~ 2.5 ppm @-40°~+85°C (depending on type)		±0.5 ~ 2.5 ppm @-40°~+85°C (depending on type)	
Current consumption	2~2.5 mA max (depending on type)			

Table 3: GEYER Electronic TCXOs

In addition to the already established new generation package types, KXO-86, KXO-84 and KXO-81, we took a further step into miniaturization last year and introduced the KXO-88 to the market across its wide frequency range.

With a footprint of only 1.6 x 1.2 mm, this TCXO is ideally suited for use in all small footprint, low power applications.

The main performance features of this TCXO family are:

- Dimension: 1.6 x 1.2 mm
- Height: max. 0.8 mm
- Operating temperature range: -30° C to +85° C
- Frequency range: 13 to 52 MHz
- Frequency stability: +/- 0.5 ppm
- Power consumption: only 2 mA max.
- Phase Noise: -145 dBc/Hz at 10 kHz

Whether electricity meter, medical diagnostic device or health tracker - our high-precision crystals and oscillators efficiently and cost-optimized fulfill the technical requirements.

CONCLUSION

Among oscillators, the TCXO market is the one that is developing the fastest world-wide, and even if unforeseen events should happen again, the current development is unstoppable.

The world is being "clocked" more and more precisely. However, not all applications require the oscillator with the best possible accuracy.
If one chooses the analogy to a highway, then each device drives with its own speed, in its own car design on the highway and should not consume much energy.
It is important to know the degrees of freedom and the limitations of the applications well - then the choice of the component is already given.

GEYER Electronic GmbH supports you in selecting the product that fits best your application from a price or performance point of view.

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