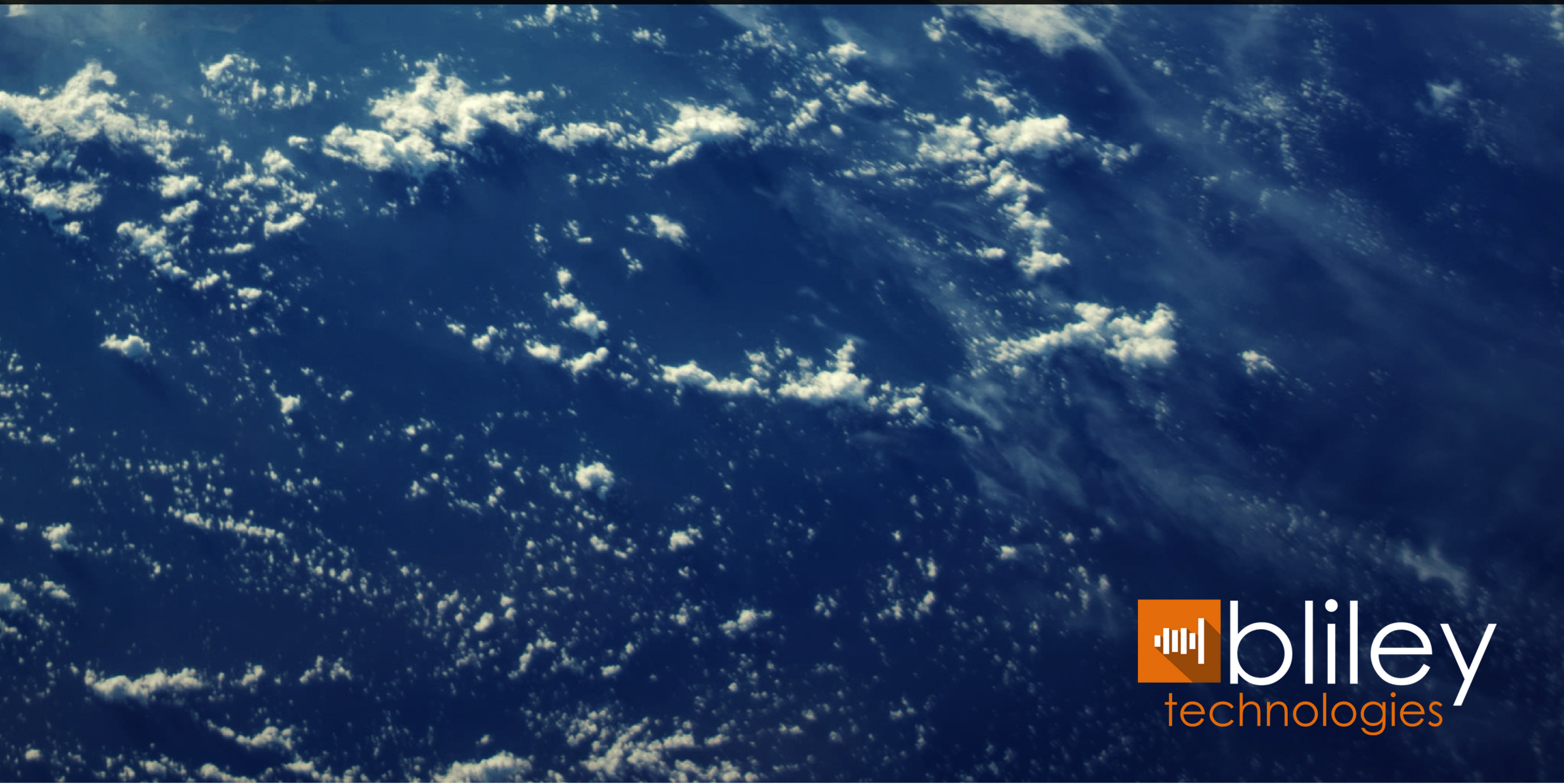
An Introduction to Common Oscillator Types

Breaking Down OCXOs, VCXOs & TCXOs



bliley technologies

If you have taken the time to download this eBook, the chances are you have a pretty good idea of what oscillators are and do.

The purpose of this publication is simple; to show the differences between the major types of oscillators as well as compare them against one another.

We well be breaking down OCXOs, TCXOs and VCXOs in this eBook. For more than 85 years, we've been crafting some of the highest performing frequency control devices in the universe.

Today we are among the world-wide leaders in the manufacturing of low noise frequency control products. We continue to find ourselves striving toward significant improvements to meet the constantly changing needs of our customers.

Tighter stabilities, lower phase noise and acceleration sensitivity as well as reductions in package size drive our development of various new technologies. We believe we are fully prepared to meet the challenges and to excel as we have done for more than 80 years.

OCXO

Oven Controlled crystal (Xtal) Oscillators, OCXOs, are used in applications where a very high degree of frequency stability is required. Sometimes these oscillators may even be referred to as temperature-stabilized crystal oscillators, or just crystal ovens.

While crystal oscillators show a high degree of stability even when the outside temperature is varied over a significant range, for some applications even higher levels of temperature stability are required. In these applications OCXOs may provide the required solution. As with many other crystal-based products, OCXOs are available in a widely variation of packages and package styles.

The performance levels and costs also need to be considered as these can vary considerably as well. Despite this it is still sometimes necessary to ensure a better degree of stability. This can be achieved by placing the crystal in a thermally insulated container with a thermostatically controlled heater. By heating the crystal to a temperature above that which would normally be encountered within the electronic equipment the temperature of the crystal can be maintained at a constant temperature. This results in a far greater degree of temperature stability.

Additionally the crystal in the OCXO will be cut to ensure that its temperature stability is optimised for the internal operating temperature. Commonly the internal temperature for a crystal oven is run at a temperature of 75°C or thereabouts. The temperature needs to be above the highest temperature likely to be encountered, otherwise the temperature control will not work.

The typical specification for an OCXO might be ±5 x 10-8 per degree Celsius (0.05 ppm), whereas a non-oven controlled oscillator may be between 10 and 100 times poorer. As the oscillator assembly will also contain buffering circuitry as well as supply voltage regulation the other characteristics of the oscillator should also be good. Typically it might be expected that frequency stability would be around ±5 x 10-9 (0.005 ppm) per day and ±5 x 10-7 (0.5 ppm) per year and 1 x 10-7 for a 5% change in supply voltage. All of these are far better than would be expected from a simple crystal oscillator.

In order to ensure that the optimum overall accuracy is maintained, combating elements such as ageing of the crystal itself, a periodic calibration of the OCXO may be required. Typical calibration periods may be of the order of six months to a year, but the actual period will depend upon the OCXO itself and the requirements of the application in which it is being used.

OCXO Physical Considerations

OCXOs are physically much larger than a simple crystal oscillator. Not only do they need to incorporate the crystal oscillator itself, but also the heater, control circuitry and the thermal insulation around the crystal oscillator.

Typically the heater will be run from a different supply to the oscillator. It does not need the same level of regulation, and indeed the oscillator is most likely to have its own regulator to remove any stray noise and RF that may appear on the supply line and thereby degrade the performance of the OCXO. The supply for the heater in the OCXO may be quite current hungry. Some units may require an Amp or so on warm up. This figure will reduce as the temperature inside the OCXO rises and less heat is needed. As will be imagined the temperature is thermostatically controlled.

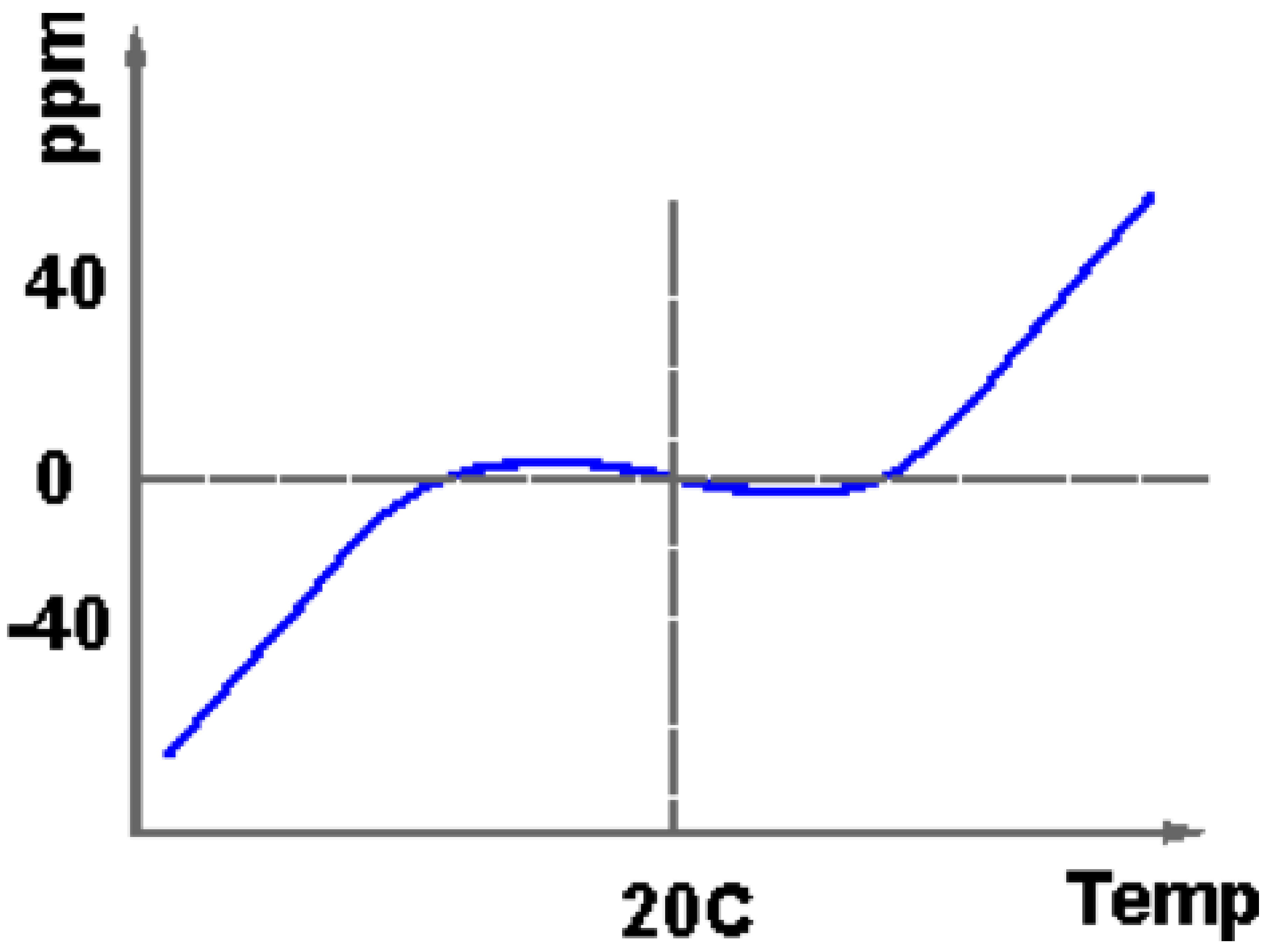
These OCXO units are naturally more expensive than crystals on their own, but the performance of an OCXO is considerably enhanced on that of a simple crystal in an unregulated electrical and physical environment.

The TCXO, Temperature Compensated Crystal Oscillator (Xtal oscillator) is a form of crystal oscillator used where a precision frequency source is required within a small space and at reasonable cost.

By applying temperature compensation within the crystal oscillator module, it is possible to considerably improve on the basic performance of the oscillator.

Effect of Temperature

Although crystal oscillators offer a highly stable form of oscillator, they are nevertheless affected by temperature. The cut of the actual crystal element from the overall grown crystal can help to minimize the effects of temperature, but they are still affected to some degree. For a crystal cut known as the AT cut, the drift with temperature can be minimized around normal ambient temperature, but the rate of drift will rise above and below this.

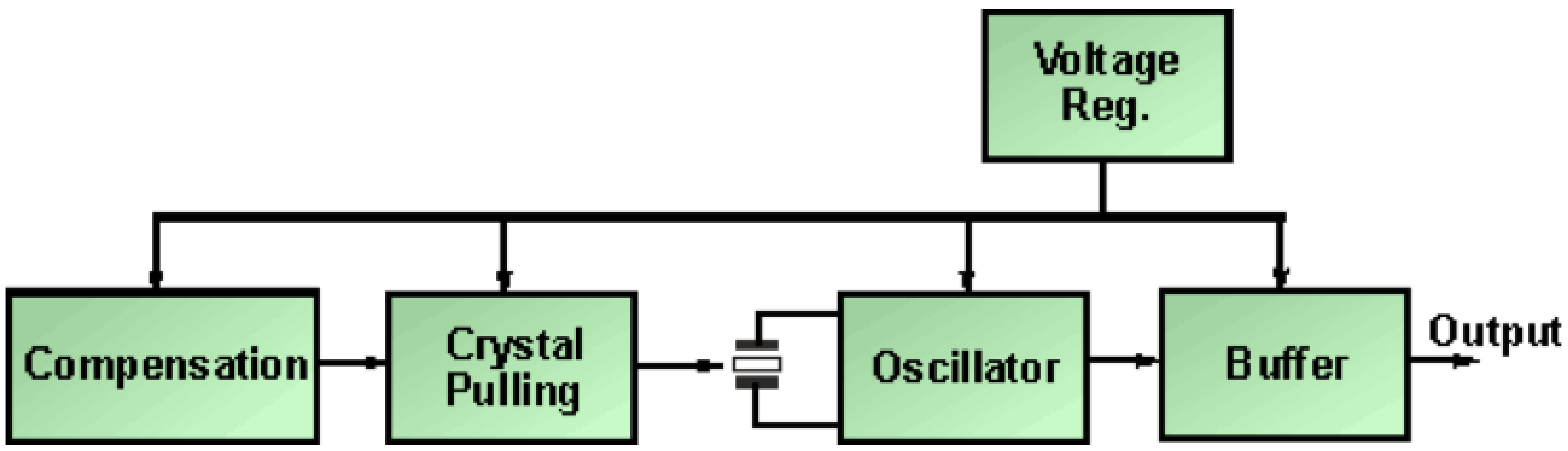


The effects of temperature are, to a large degree, repeatable and definable. Therefore it is possible to compensate for many of the effects using a temperature compensated crystal oscillator, TCXO.

TCXO

A TCXO adjusts the frequency of the oscillator to compensate for the changes that will occur as a result of temperature changes. To achieve this, the main element within a TCXO is a Voltage Controlled Crystal Oscillator (VCXO).

This is connected to a circuit that senses the temperature and applies a small correction voltage to the oscillator as shown below



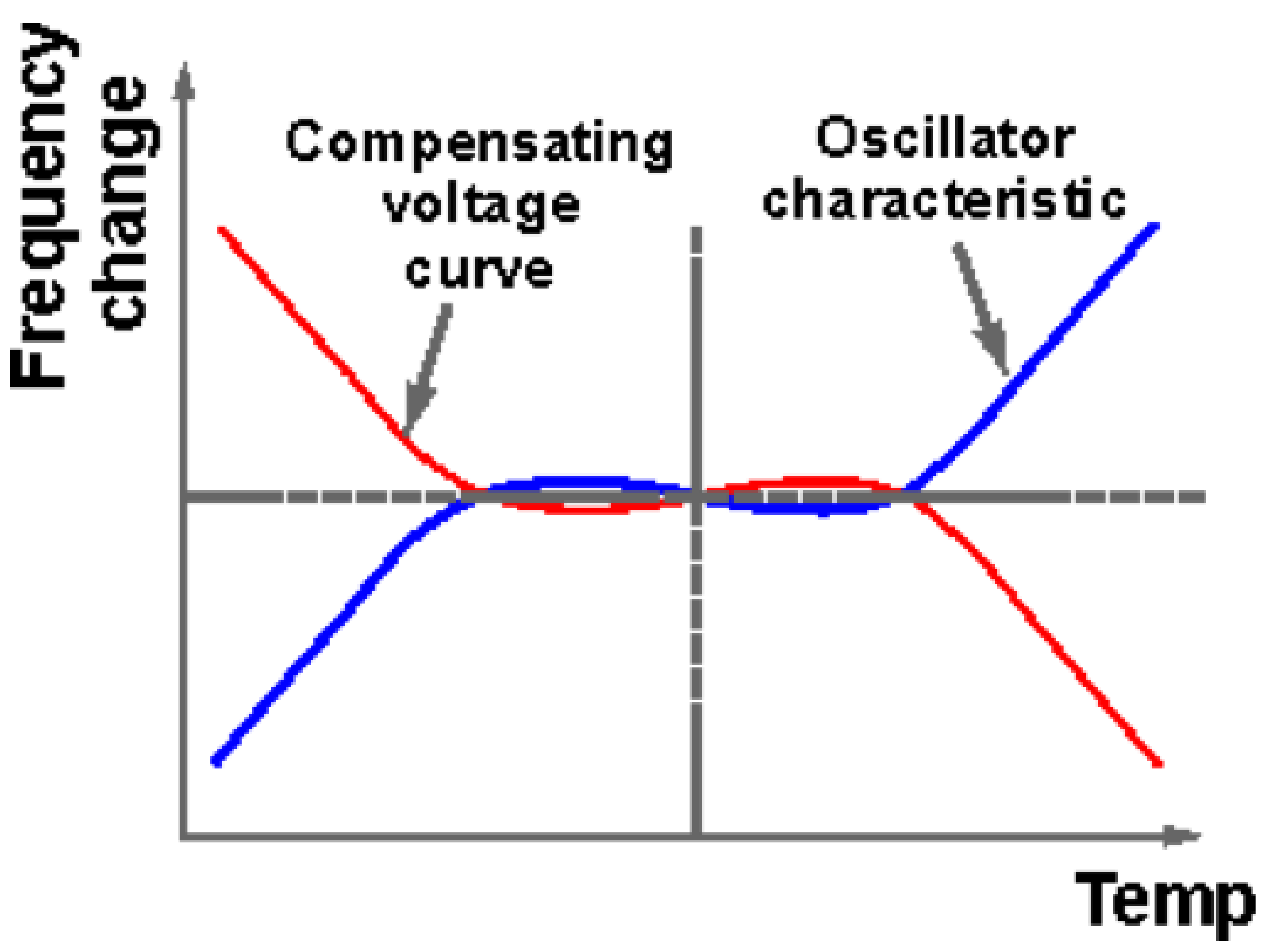
There are a number of different elements that comprise the overall temperature controlled oscillator; compensation network, oscillator pulling circuit, crystal oscillator, voltage regulator & buffer amplifier.

Additionally TCXOs normally have an external adjustment to enable the frequency to be reset periodically. This enables the effects of the ageing of the crystal to be removed. The period between calibration adjustments will depend upon the accuracy required, but may typically be six months or a year. Shorter periods may be used if very high levels of accuracy are required.

Compensation Network

The compensation network is the key to the operation of the whole system. An approximate curve for the temperature frequency response of the oscillator is seen above. The actual curve can be expressed approximately in the form of a 3rd order polynomial expression, although a more accurate representation takes into account some non-linearities and works out to be close to a 5th order polynomial. The compensation network needs to sense the temperature and produce a voltage that is the inverse of this.

Early designs would have used analogue circuitry and often directly used a network of capacitors, resistors and thermistors to directly control the frequency of oscillation. This type of circuit included both blocks on the diagram of the compensation network and the crystal frequency pulling block.



Currently, technologies typically adopt an indirect approach where the temperature is sensed in the compensation network, and a voltage is generated that provides a frequency change that is the inverse of the temperature curve. This can be achieved using analogue components, but current technologies often incorporate some form of digital signal processing to be able to generate a far more accurate response, with the possibility of linearising units separately by programming a ROM with the response of the particular oscillator. The DSP circuitry is often contained within a special ASIC to enable it to be tailored to suit the application without draining too much current.

Oscillator Pulling Circuit: Once the voltage has been generated, this is applied to a circuit that can pull the frequency of the crystal oscillator. Typically this incorporates a varactor diode and some low pass filtering.

Crystal Oscillator: The oscillator circuit is normally a standard circuit, but one that is designed to give The oscillator circuit is normally a standard circuit, but one that is designed to give the operating operating conditions for the crystal with ideal drive levels, etc.

Voltage Regulator: In order to prevent external voltage changes from introducing unwanted frequency shifts, the overall TCXO should incorporate a voltage regulator which itself should not introduce unwanted temperature effects.

Buffer Amplifier: A buffer amplifier is required to give the increased drive to the output. It should provide isolation to the crystal oscillator from any external load changes that may be seen.

TCXO Performance

Some of the main performance figures are summarized below:

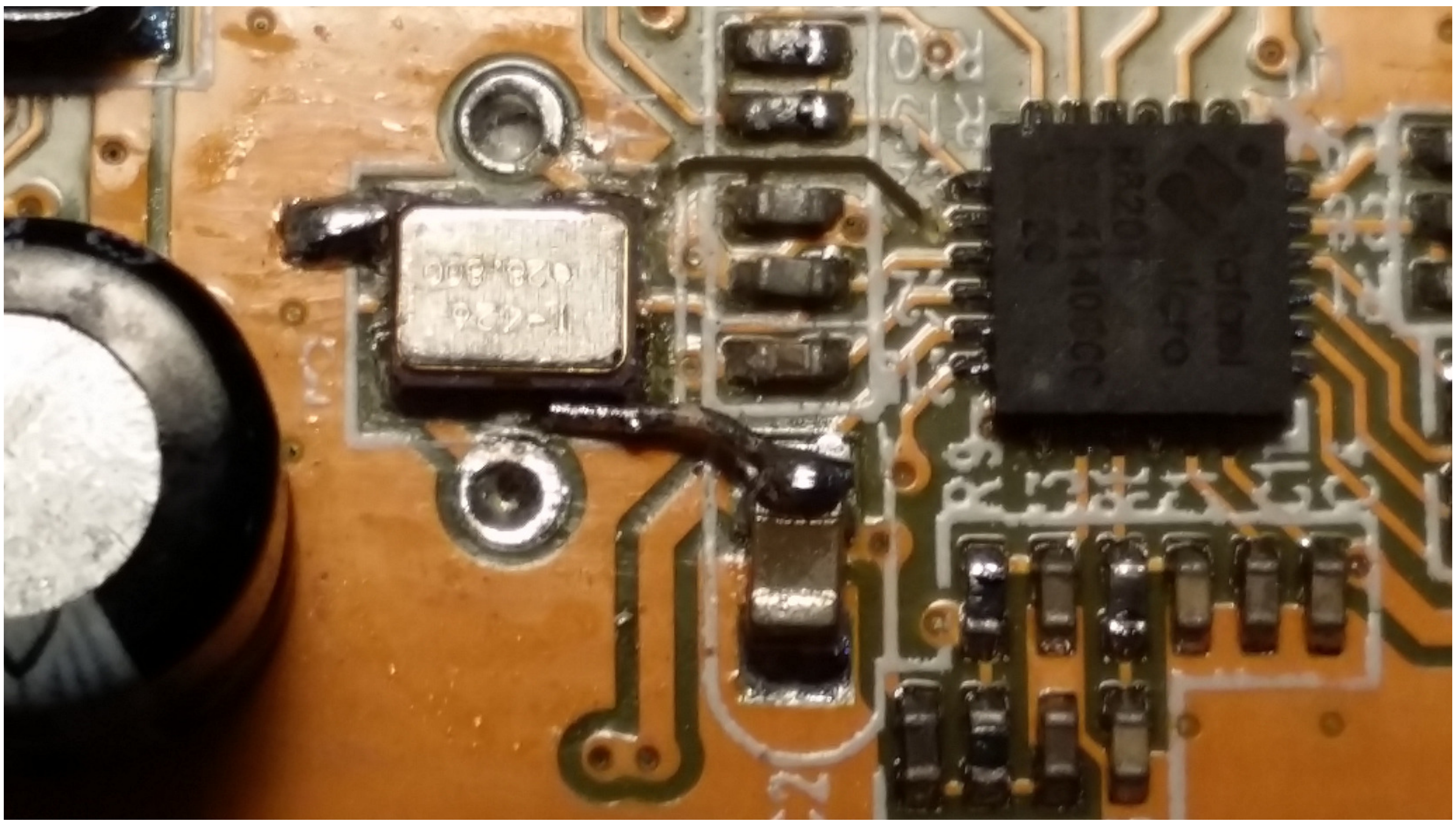
TCXO PPM performance: The TCXO temperature performance is better than that of a normal crystal oscillator. Typically figures of between 10 and 40 times improvement can often be seen. Typical figures are given in the table above for the different temperature ranges. Figures of better than ±1.5 ppm over a 0 to 70°C temperature range are difficult to achieve as they then fall into a high precision category where costs increase significantly.

Power dissipation: The power dissipation of a TCXO will be greater than an ordinary oscillator in view of the additional circuitry required. Additionally the cost is greater. It should also be remembered that it will take a short while after start up for the oscillator to stabilize. This may be of the order of 100 ms, or possibly longer, dependent upon the design.

TCXO package: TCXOs can be supplied in a variety of packages dependent upon the way they have been designed and the requirements of the end user. The most common form of construction is to construct the circuit on a small printed circuit board that can be house in a plat metal package. This is then suitable for mounting onto the main circuit board of the overall equipment. As the crystal itself is sealed, this means that sealing of the overall TCXO package is not critical, or even required for most applications. Package sizes such as 5x3.2x1.5 mm or 5x3.5x1 mm are widely used for TCXOs and smaller packages available if required.

Output format and level: With many TCXOs being used for driving digital circuits, most of the small oscillator packages produce what is termed a clipped sine wave. This is suitable for driving a logic circuit, although in many cases it is wise to put it through a logic buffer to ensure it is sufficiently square. Often the output is an open collector circuit. If a sine wave output is required, then this must be chosen at the outset and it will limit the choice available.

Power requirements: The actual power requirements will depend upon the particular device. Many operate from supplies of 3 V, and may draw as little as 2 mA, although this will depend upon the general type, the manufacturer and the particular device chosen.



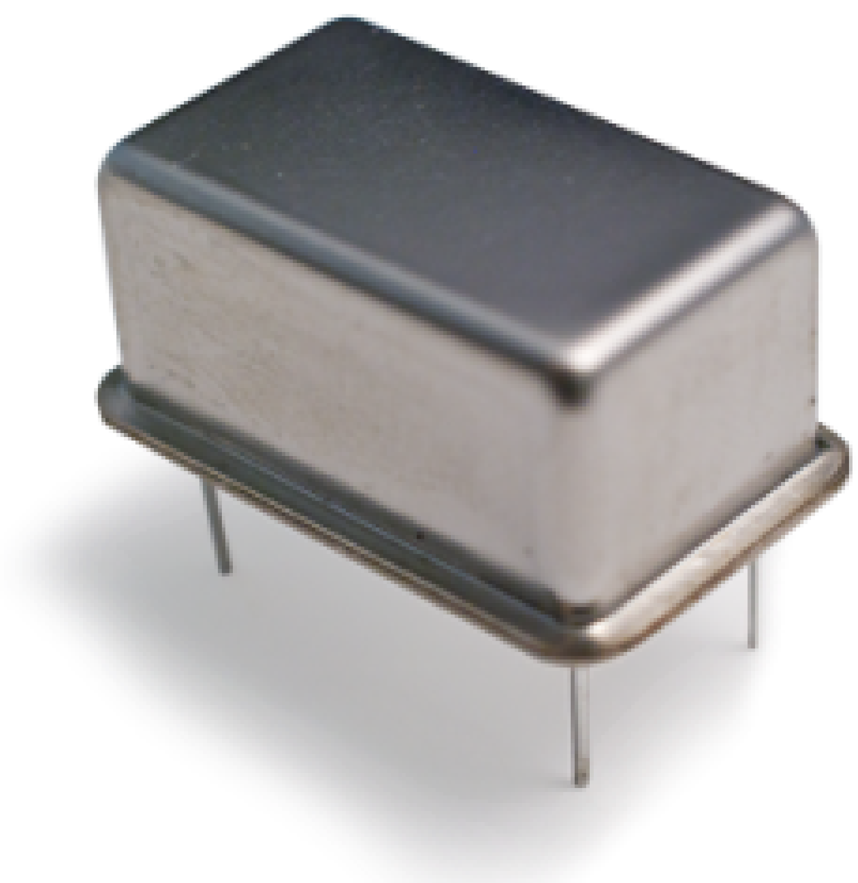
VCXO

VCXOs are used in many applications. They are used in TCXOs where the temperature compensation voltage is applied to a control terminal of the VCXO. In this way the drift can be considerably reduced, although the performance is still not as good as a full oven controlled crystal oscillator.

In another application, VCXOs are often found in narrow band phase locked loops where only a small amount of frequency variation is required.

Naturally the fact that the frequency of the VCXO can be pulled reduces the overall performance of the oscillator circuit. The phase noise performance of the oscillator is degraded because the effective Q of the resonator is considerably reduced. Additionally the frequency stability is not as good.

One of the major problems with VCXOs is that of temperature drift. As this varies over the voltage control range, it cannot be optimized for all levels of control voltage, the final design being a compromise. This when used without other forms of temperature compensation they may drift more than other forms of crystal oscillator



Specifying VCXOs

Many VCXOs are ordered as modules from a specialist supplier of these items. It is necessary to specify them correctly to obtain the required product.

When specifying a VCXO the following parameters are normally needed:

Frequency: This is normally specified in MHz for frequencies over 1.0MHz and in kHz below this. It also needs to be specified to the correct number of decimal places to enable the manufacturer to be able to determine the required frequency needed. Refer to the manufacturers details for the correct number - typically six or seven significant figures.

Output: VCXOs are required for a number of applications. Some may be sued to drive different forms of logic, whereas others may be required for analogue applications. The output requirements are an important element of the overall specification.

Frequency stability: Even though VCXOs are variable, the basic frequency stability still needs to be specified. Generally this is done for room temperature, 20°C and with the voltage control point set to its centre value. The frequency stability is taken for operation over the operating temperature range. The value is specified in terms of parts per million, ppm. Standard stability specifications are typically ±25ppm, ±50ppm and ±100ppm

Supply voltage: It is necessary to specify the supply voltage to ensure that it operates within the unit for which it is intended. Ideally it should be able to operate outside the expected tolerance of the supply so that any slight mismatch does not cause an issue.

Operating temperature range: Most units have a temperature operating range over which they will function. Accordingly it is necessary to specify a range for the VCXO.

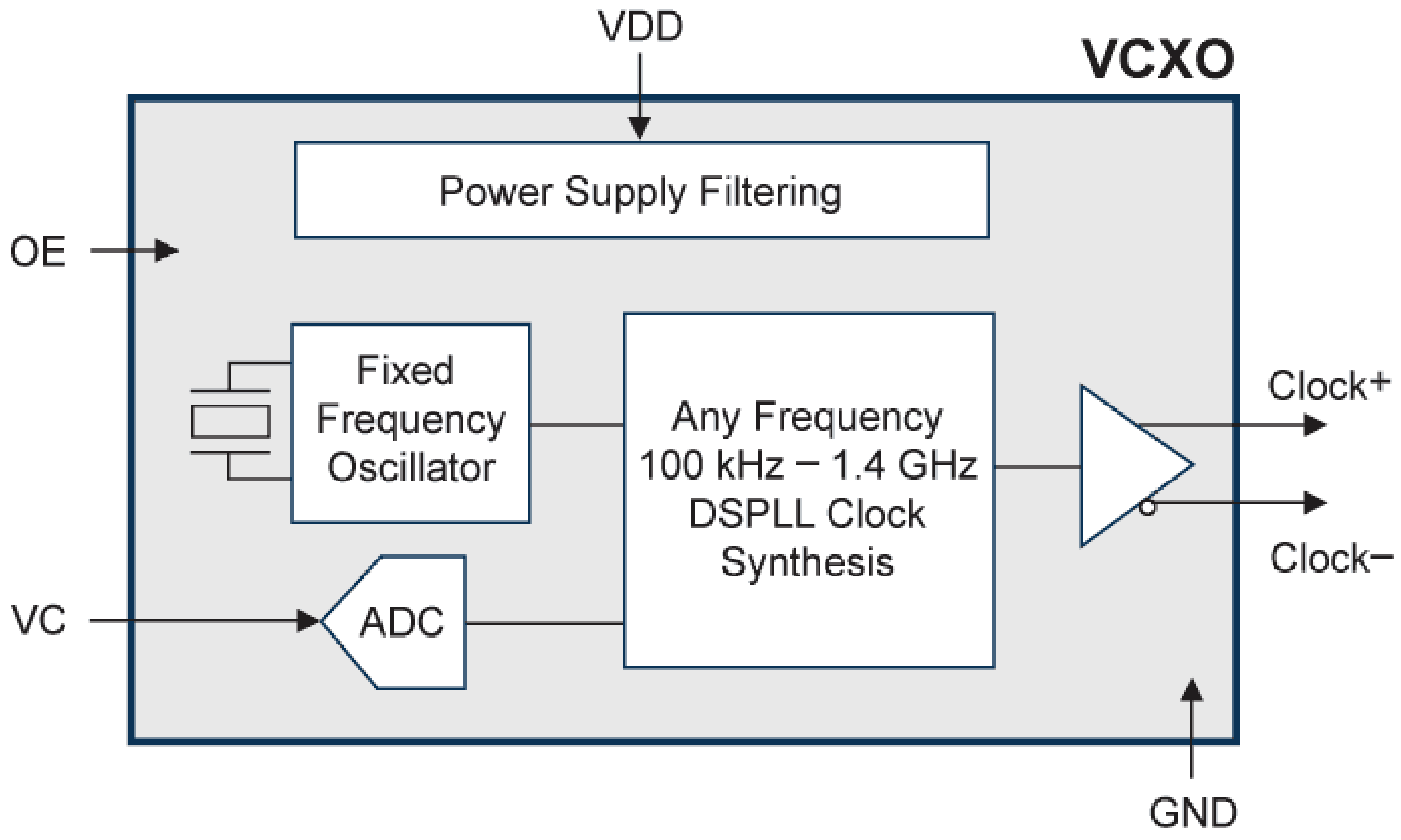
There are three main ranges:

> 0 - 70° C - Often referred to as a commercial temperature range. It is normally satisfactory for operation within office or laboratory environments.
>
> -10 - + 70°C - Industrial range which is needed where temperature ranges may fluctuate more widely.
>
> -40 - +85°C - this is nearing the military range (normally -40 to +125°C) and is required where much larger temperature ranges are needed. For example for equipment that may be used externally.

It should be remembered that there is often a temperature rise within an item of equipment and this means that components will be operating well above the ambient external temperature. This must be taken into consideration when determining what temperature range may be needed.

Pullability: The pullability is the frequency range over which the VCXO can be pulled for a given change in control voltage. It is specified in terms of parts per million, ppm, for a given voltage. As is expected, large pullability figures give a larger tuning range, but VCXOs will smaller levels of pullability offer greater stability and lower phase noise.

Package: It is necessary to specify the package as VCXOs come in many forms and various options may be available from through hole mount to surface mount. Also options such as tape and reel are often available for large scale manufacture using automated manufacturing machinery.



Comparing Oscillators

	VCXO	TCXO	OCXO	LP-OCXO
Supply Current	20-40 mA	2-20 mA	150-300 mA*	30-75 mA**
Frequency vs Temp (-40 to 85)	10-20 ppm	.5-10 ppm	.002-.5 ppm	.005-.1 ppm
Initial Frequency	2 ppm	1 ppm	.1 ppm	.1-.2 ppm
Aging	3 ppm/year	1 ppm/year	.05-.5 ppm/year	.05-.15 ppm/year

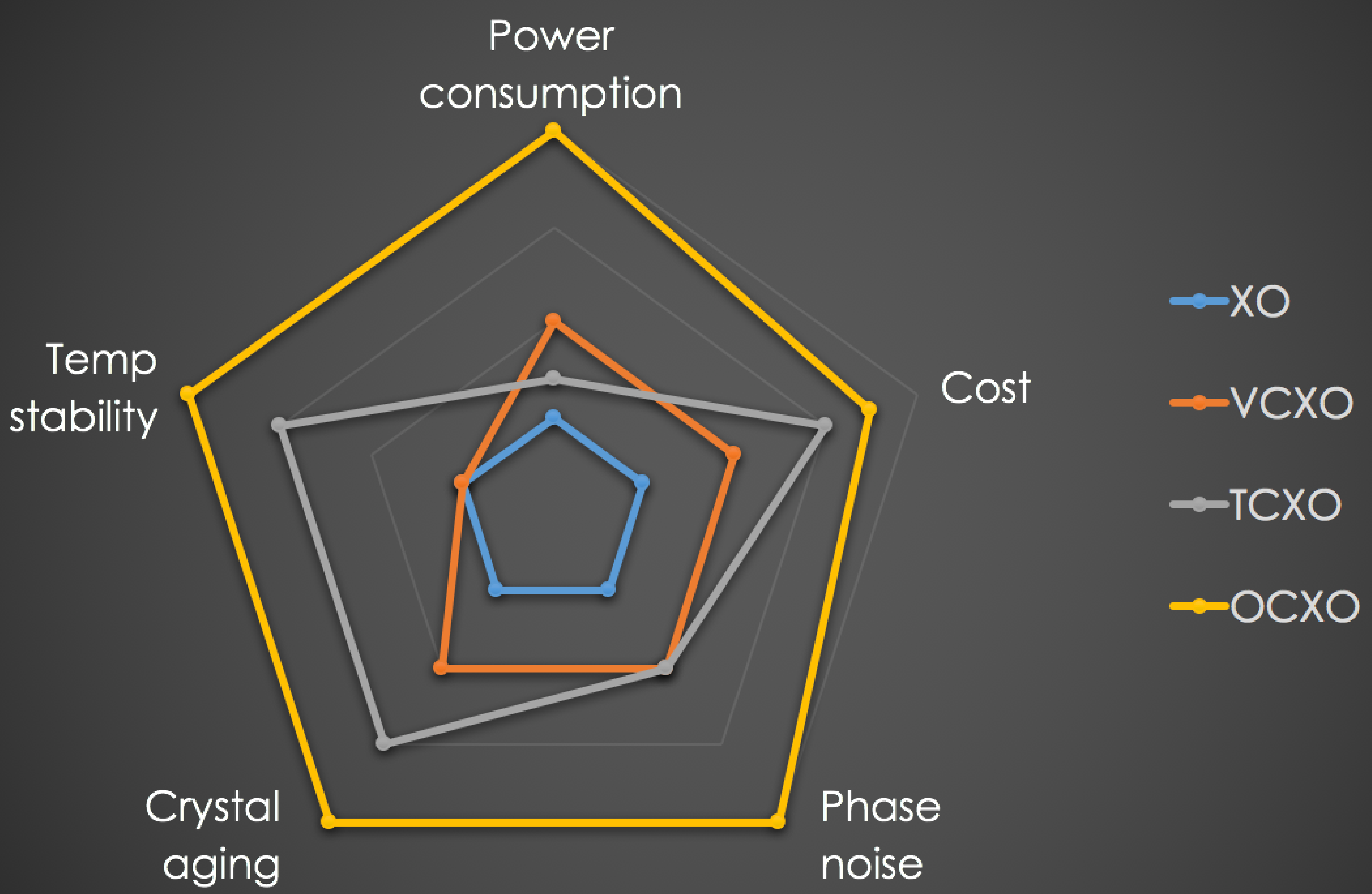
- OCXOs also have a startup current of 200-600 mA until the oven comes up to temp

** LP-OCXO startup current is 60-450 mA depending on manufacturer

General Phase Noise data

	VCXO	TCXO	OCXO	LP-OCXO
@1 Hz	-70	-70	-90	-90
@10 Hz	-100	-90	-120	-125
@100 Hz	-130	-120	-140	-145
@1 KHz	-140	-135	-150	-155
@10 KHz	-150	-145	-160	-160
@100 KHz		-150	-160	-165

Picking the best oscillator for your application



The LP 102A Low Power OCXO

"The goal with our LP102 product line was to offer the highest performance that is expected from a Bliley part, but with a power budget that is a fraction of standard OCXOs," stated Tommy Reed, Bliley's VP of Technology.

Commenting on the LP102s availability, Greg Rogers, VP of Products, said "the LP102 is currently sampling with full production expected later this quarter,"

Get the full data sheet for the LP102 here.