What's in Your Oven?

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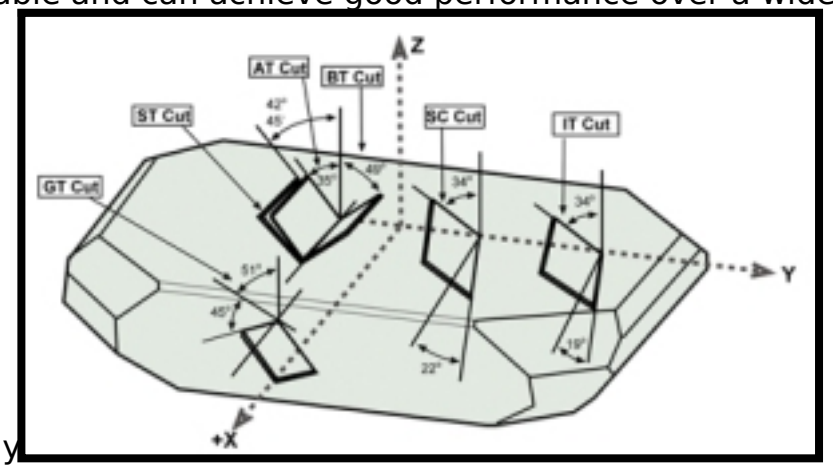
How to choose the correct oven oscillator for your application

What happened to the days of picking a simple 10MHz oven oscillator to work in your circuit? You knew it would be big (2" by 2"), power hungry (at least 2 watts), and more precise than any other oscillator you could find. Oh yes, there is one more attribute you could expect, it would be EXPENSIVE! You needed a good reason to use it, but if that was the requirement, you begrudgingly designed it in.

Like most things in our lives, the more choices we have, the more complicated the decisions. Picking an oven oscillator (OCXO) is no exception. Today we have AT-cut and SC-cut crystals, package sizes from 9x14mm to 50 x 50mm, phase noise - both "close in" and the "floor", low power, high power, frequencies from 10MHz to 250MHz , fundamental, third overtone, fifth overtone, multipliers, dividers, aging and on and on…. With more and more choices to evaluate, specifying the correct part is more complex than ever. . How do you know what is right for your design? Let's take a look at some OCXO characteristics and try to narrow down the choices:

The heart (beat) of an oven oscillator is its crystal. Like all oscillators, the piezoelectric effect of the crystal is what generates the frequency. Historically, OCXOs have used SC-cut crystals but more recently, AT-cut crystals have shown up in lower-cost devices. The cost difference can be easily explained by simple supply and demand: SC-cut crystals are almost exclusively used in oven oscillators (~ 3% of the oscillator market); AT-cut crystals are used in the rest of the oscillator market. The real question is, what's the difference?

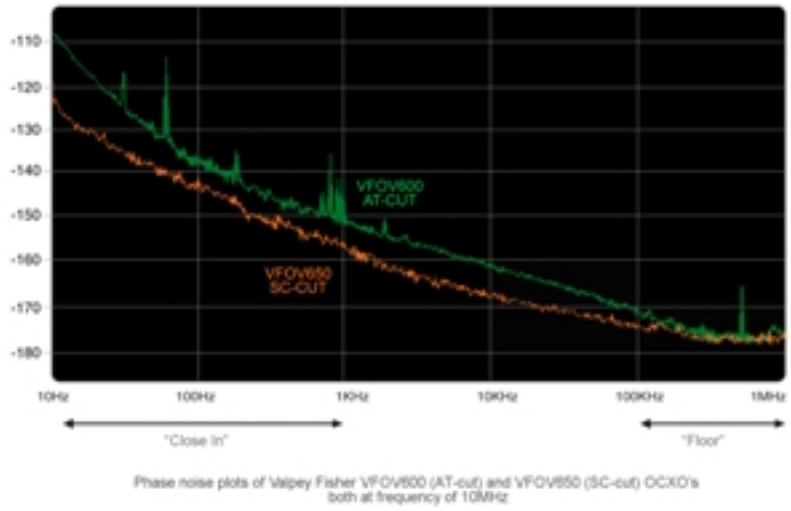
AT-cut crystals are widely available and can achieve good performance over a wide



frequency range. They are easily processed and do not require the precision cuts that SC-cut crystals need. They have good characteristics to be used in Oscillators (stability), Voltage Controlled Oscillators (electrically "pullable" or adjustable) and Temperature Controlled Oscillators (combine temperature stability and adjustable in a single circuit).

SC-cut crystals are harder to manufacture. The cuts need to be precise in the X, Y, and Z axes versus the X and Y axes for the AT-cut crystal. They have poor frequency stability over a wide temperature range and are not very "pullable". However they do have some unique characteristics that make them an excellent choice for an OCXO. Temperature stability is the most notable; when the temperature remains stable (ie in an oven) the SC-cut crystal is approximately 10 times more stable than an AT-cut crystal. SC-cut crystals also age better and are much more predictable over time than an AT-cut crystal is. SC-cut crystals also have fewer abnormalities for the oscillator design to avoid such as activity dips and coupled modes. All of these characteristics of an SC-cut crystal give it a higher quality factor or "Q" than an AT-cut crystal has.

The Quality Factor (Q) is not something that you will see in a specification or a characteristic you can ask for by name. The most common way to see the "Q" of an oscillator is to look at the phase noise plot (frequency domain measurement of jitter) of the oscillator. The lower the phase noise, the higher the "Q" factor. The phase noise plot is commonly thought of as having two distinct sections; "close in" and the "floor." Close-in phase noise is the curve from an offset of 1 Hz to 1 kHz; the floor is usually at an offset beyond 1MHz. The biggest influence on close-in phase noise is the crystal while the noise floor is mostly influenced by the oscillator circuit and output buffer. Close- in phase noise for a SC-cut crystal is often 15 to 25 dBc/Hz better than AT-cut crystals while the noise floor is similar.



Close In **Floor***

Phase noise plots of Valpey Fisher VFOV600 (AT-cut) and VFOV650 (SC-cut) OCXO's both at frequency of 10MHz

Different applications require better phase noise at different frequency offsets. Designers of radar and other graphical applications are looking for the lowest phase noise close to the carrier. Better phase noise in this region gives better reflectivity of objects. As mentioned above, SC-cut crystals offer better close-in phase noise. Telecommunications designers often ask for phase noise between 12 kHz and 20 MHz, an industry standard in the mid band of the phase noise plot. Designers of phase lock loops (PLL), Analog to Digital converters and Digital to Analog converters

are all looking for a lowest phase noise floor so their circuits do not amplify the noise and add it into their system. AT-cut crystals offer the best price/performance and are usually chosen for these types of applications.

Now that you have a better understanding of the types of crystals used in oven oscillators and their respective advantages and disadvantages---let's take a look at some of the other characteristics that affect the price of an OCXO.

How to save money when specifying an OCXO

AT-cut versus SC-cut:
Having read the section above, it may be obvious which crystal type is needed for your application. If it's not, don't specify it. Tell the supplier what the phase noise requirement is and let them tell you what the best solution is.

Stability:
Stability is usually the first characteristic associated with an OCXO. It is a major cost driver and can be specified over several conditions such as temperature, voltage changes, and periods of time (usually days or years). Rather than specifying your requirement over each of these variables, use an all inclusive number. This allows the supplier to allocate the stability across all the variables in the most cost effective way.

Aging:
Aging is the amount (in ppb) an OXCO changes with time. Crystals can be processed to age at different rates. More processing (hence more cost) goes into devices that age slowly over short periods of time (1 day). If possible, specify the longest aging time your system can tolerate. Yearly (or if possible lifetime) aging will save the most money.

Temperature:
As previously mentioned, crystal stability varies over temperature. Maintaining a stable temperature (inside an oven oscillator) is harder to do over a wide temperature range. At lower temperatures this seems obvious but even at high temperatures it makes a difference. A part made to work in a 70 degree Celsius (oC) environment uses a different (and less expensive) crystal than one manufactured to work at 85oC. Choose the least amount of ambient temperature variation your system will see (i.e. 0 to 50oC) to save the most amount of money.

Frequency:
If given a choice on frequency, 10MHz is the most commonly used OCXO frequency and will be the most available in times of need. Prices will also be more negotiable due to total supplier volume.

Sub-Harmonics:
Many manufacturers offer OCXOs at frequencies over 100MHz. An overtone or a multiplying scheme is typically used to get to these higher frequencies. Overtone crystals offer a higher "Q" but are more expensive. Multiplying may cause sub-harmonics. If possible, plan for sub-harmonics as high as -30dBc to save money at

higher frequencies.

Through-Hole Versus Surface Mount:
The majority of packages sold today are still built with through-hole mounting. This is mainly due to the package size and power requirements of the devices. Larger packages use larger crystals which are easier to stabilize. Unfortunately, they are also harder to heat so more power is used. If your volumes are low, consider using a through hole package to get the best part for the lowest price. If you require surface mount, you will need to be willing to make some tradeoffs in price, performance, and availability.

Output Type:
CMOS is the least expensive and offers the best phase noise. Sine is a good option but is usually limited to +7dBm. Avoid PECL or LVDS as they add considerable expense to designs.

Supply Voltage:
In today's technology, a 5 V supply is still optimal. Many designs offer 3.3V but at a higher current. Remember there is an electric heater in every device and Ohm's Law still applies so the total power in a 5V and 3.3V designs will be the same.

Quality (the hidden cost):
When choosing a supplier for an OCXO, look for a company that has a proven history of designing and building them. Today there are many OCXO suppliers that were not even around 5 years ago. An important caution: Cheaper is not always better. There are many subtleties in the design and manufacture of these devices that can change over time and adversely affect an application. Stick with a supplier that can translate your requirements into a product that meets your price and performance needs.

Today, choosing an OCXO for your application is not as simple as it once was. There are choices that were not available in the past. Knowing what the choices are and how they might affect your application is the best way to pick the most cost competitive OCXO. If you get stuck, talk to a supplier that has a history of making industry leading devices.

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Posted by Janine E. Mooney, Associate Editor

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