Precision Timing Options for Wireless Applications

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With the explosive growth of wireless communication, wireless equipment manufacturers are continually seeking ways to reduce the cost of their designs without sacrificing performance. Case in point is the low cost microcell, a sub $200 mini base station used to offload cell station traffic to a broadband connection within a customer premise location. In an effort to reduce overall cost, although the requirement for precision timing remains, the budget for precision timing has become a prime target for cost reduction.

Fortunately, lower cost solutions are emerging to satisfy these precision timing requirements. However, the new components available can blur the defining line between what was traditionally thought to be required for these applications. To accomplish the goal of balancing performance requirements versus cost reduction, a designer must understand the critical needs of the application, including any standards-based requirements and environmental considerations required or, more importantly, not required. When identifying a precision timing strategy, specification “creep” can interfere with the goal of cost reduction given various factors that dictate the physical configuration of the timing component.

TCXOs vs OCXOs

It is generally understood that TCXOs are lower cost devices than OCXOs, in terms of price and power consumption. Until now, TCXOs were not able to approach the frequency stability over temperature when compared to an OCXO. With improved compensation techniques and advanced semi conductor integration, new TCXO products can provide frequency stabilities over wide temperature ranges down to &#177 50ppb, the same as loose tolerance SC crystal based OCXO. As equipment becomes more mobile, current draw can be critical and a TCXO draws less than 5mA where almost any OCXO requires a minimum of .25A and upwards of .5A upon warm-up.

A TCXO requires virtually no time for warm-up to get to Fo. An OCXO requires anywhere from 2 to 3 minutes up to 10 minutes. Depending upon the precision level, an OCXO can require hours or days to fully stabilize to the level desired. If the application requires adherence to an industrial temp range, an OCXO must be designed to operate internally at temperatures that are roughly 10° C above the maximum operating temperature. Not only does this drive cost, but also impacts long term reliability when the circuit operates at elevated temperature over long periods of time.

Although stability ratings may appear to be similar between an OCXO and a TCXO, the characteristics of each can be unique under different environmental conditions. OCXO temperature curves are generally smoother. Because an OCXO compensates for frequency variations by directly heating the crystal to a very narrow (
Since a TCXO directly compensates for frequency variations over temperature by

changing the reactive elements within the crystal circuit, the crystal design is optimized where the crystal curve is symmetrical and very linear. A nearly equal but opposite reactive curve is generated to 'cancel' or 'pull' the natural cubic frequency curve of the AT Cut Quartz crystal as close to zero offset as possible. The result is compensation curves that will move slowly up and down in frequency within the specification band while the temperature changes. Rapid temperature fluctuations can have a more immediate effect on a TCXO than an OCXO due to the fundamental nature of the design of each component. Further, the crystal resonator may have some inherent characteristics that are dampened when the temperature surrounding the crystal is maintained by the oven, rather than the crystal seeing the extent of the temperature gradients in the operating environment. This effect is referred to as "hysterisis" and can be measured when a reciprocal temperature change takes place. In an OCXO specification, this is often referred to as "retrace" which identifies how closely the frequency response maintains itself over continuous warm-up conditions or reciprocal temperature cycles.

Quartz Options in OCXO Products

To achieve frequency stability performance beyond the capability level of a TCXO, ovenized oscillators are generally used. Within this category, there are many options available with a wide range of costs. While smaller DIP OCXOs have been available for some time, new, lower cost designs are now available in even smaller packages, such as 9 x 14 mm SMD. These small components can provide frequency stability levels that can achieve as low as &#177 20 ppb over a wide operating range and cost less than half that of your typical SC crystal based OCXO. However, the crystal unit design used in these devices differs significantly from one found in a much more expensive OCXO, even with the same stability rating over temperature.

The most visible differences among the various quartz design options are in the categories of daily aging rates, short term stability, and phase noise levels. Typically, the more mass, i.e. the thicker the quartz plate, the higher the "Q" levels can be achieved. This is beneficial in achieving lower phase noise, better aging rates and better short term stability. Thus, the thicker the quartz plate, the lower the frequency, and the better opportunity to achieve higher "Q" levels translates into lower close in phase noise, improved aging performance, and better short term stability. Stability over temperature remains a function of maintaining a constant temperature. More expensive OCXOs at 10 MHz might utilize a 3.33334 MHz fundamental SC resonator operating on the third overtone at 10 MHz to provide the opportunity for better aging rates, better phase noise and better short term stability than 10 MHz fundamental SC or AT resonators. Similarly, due to various differences in the characteristics of AT cut resonators versus SC cut resonators, a 10 MHz fundamental SC resonator will provide better results in these areas than a 10 MHz fundamental AT cut resonator. Table 1 shows some typical results achieved with each quartz design option.

Physical package size and case height are also significant factors in specifying an OCXO, depending upon the need to optimize performance in one category or another. Obviously, the quartz wafer design needed to address any one of these specifications will dictate the overall dimensions of the OCXO package. In addition, optimizing the thermal characteristics of the OCXO requires insulating properties around the quartz wafer. Dead air space provides effective insulation which increases with the height of the package. As PCBs become more dense and crowded, component height can be a limiting factor. Although there are ways to reduce the height of an OCXO, performance related effects in maintaining a stable thermal environment under those conditions must be considered. The difficulty for the designer responsible for specifying a precision timing component is to keep all of the aforementioned specifications in perspective in relation to each other. Any one of these specs can drive the component design and dictate an inflated cost. Understanding that these physics based relationships exist in the design of these component is the first step.

Combined Technologies

With the commoditization of GPS components, new, low cost options are available that combine the long term time precision derived from the atomic clocks in the GPS satellite constellation with good short term performance from TCXO and OCXOs. GPS disciplined oscillators using either TCXO or OCXO holdover options can provide long term frequency stability equivalent to an atomic standard at a fraction of the price and a fraction of the size. While locked up to the satellite, the receiver generates a 10 MHz output that will vary over a wide temperature range in the area of &#177 .1ppb.

To improve output characteristics and allow for situations where a loss of satellite lock occurs, an onboard OCXO or TCXO can provide short term holdover functions and generate all output parameters. Calibration error is eliminated as the disciplined oscillators are corrected continuously during lock up and the only aging that will occur is during holdover. The effects of that short term aging will be eliminated once locked up again to the satellite along with an algorithm that "learns" the aging characteristics of the holdover oscillator during lockup and further reduce the aging affect during the short hold over periods. Warm up time is eliminated upon lock up and no special design issues need be overcome in the lockup mode for operation over an industrial temperature range. This is an excellent option for mobile applications that require intermittent but extremely precise timing.

Many new component options are available to help reduce the precision timing budget for wireless equipment designers. Defining the applications' fundamental requirement, however, is critical to keep from over-specifying precision timing devices that may drive needless cost into the design.

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Figure 1. Typical OCXO vs. TCXO Hysterisis. Figure 2. OCXO vs. TCXO Phase Noise Comparison. Figure 3. FTS375 GPS Disciplined OCXO in Lock, Holdover and Relocked Conditions. Table 1. Typical Phase noise results for different Quartz Crystal Cuts **Daniel R. Olp Vice President and General Manager dolp@conwin.com**