Advantages of Using SaRonix xP Clock Technology in High Speed Applications

Brandon Ogilvie, Craig Taylor & Thinh Ha

Introduction

For high-speed applications such as 1/10 Gigabit Ethernet, FibreChannel, SAS, and SONET/SDH, the three main technologies used to generate reference clock signals are PLL synthesizers, third overtone oscillators, and SAW oscillators. While each technology offers distinct advantages with respect to performance, cost, or reliability, each technology also possesses certain disadvantages in some of these key areas. In early 2005, SaRonix, a Pericom subsidiary, introduced an innovative new approach to high frequency clocking, nicknamed xP Technology, for 100 MHz and faster reference clocks. The new xP Technology surpasses each of the three legacy technologies in the aforementioned key performance areas.

SaRonix xP vs. PLL+crystal Synthesizers

Phase Locked Loops (PLL) are used widely in a variety of applications, including clock/data recovery, jitter attenuation, and frequency synthesis. In clock synthesizer applications, PLL circuits often consist of a high-frequency VCO (voltage controlled oscillator *without* internal crystal, a different technology than a VCXO *with* an internal crystal), phase detector, loop filter, and dividers that are integrated onto a single piece of silicon, as shown in **Figure 1**. A separate low-frequency quartz crystal reference, usually in the range of 10 to 30 MHz, stabilizes the PLL clock chip's frequency accuracy. The crystal provides a highly stable frequency reference (better than ±100 ppM) to which the PLL circuit establishes phase lock of the integrated VCO. By establishing phase lock of the high-frequency VCO with the low-frequency crystal, the VCO's long-term accuracy (> 0.1 sec), expressed as stability and measured in ppM (part per Million), becomes that of the crystal.

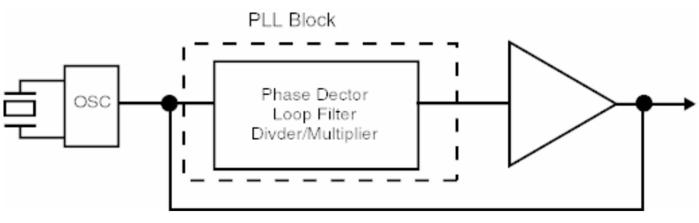

Figure 1: PLL+crystal Block Diagram

The primary advantage of a PLL-based clock synthesizer is cost – the entire clock circuit is integrated on a monolithic IC and paired with an external low-frequency quartz crystal, providing a solution cost that is less than that of other high-frequency clock technologies.

The primary disadvantage of an integrated PLL synthesizer is performance. Silicon-based VCOs – the source of the high frequency clock – exhibit a relatively low Q-factor when compared with high Q-factor direct-output overtone crystal and SAW oscillators. The frequency of the VCO modulates constantly as the PLL circuitry fine-tunes the control voltage level in order to maintain phase lock with the crystal reference. Consequently, integrated PLL synthesizers exhibit the highest magnitude of short-term error (<0.1 sec), often expressed in terms of Jitter or Phase Noise. In high-speed applications, jitter and noise deteriorate system performance by increasing the system's Bit Error Rate (BER). In many cases, practical application of PLL-based clock synthesizers in such applications has proven unsuccessful.

Figure 2 compares the typical phase noise of the SaRonix xP Technology (in red) with the typical phase noise of a high-end PLL chip (in blue). The SaRonix xP Technology is a non-PLL, patent-pending clock circuit integrated onto Pericom silicon that achieves not only superb long-term stability, but also remarkably low short-term jitter. The lower phase noise of the SaRonix xP Technology provides a significant reduction in a system's overall Bit Error Rate, thereby raising system performance well above that achievable with PLL-based clock synthesizer technologies.

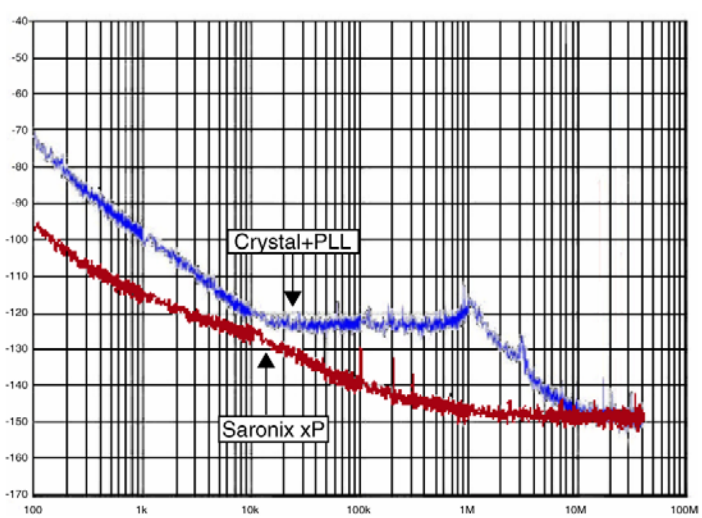

Figure 2: SaRonix xP vs. PLL+crystal Phase Noise

A secondary disadvantage of PLL-based solutions is that the overall component count and PCB real estate is higher than other oscillator technologies. PLL-based solutions are multi-chip (IC + crystal) placed side-by-side on the PCB. Conversely, overtone, SAW, and xP oscillators are single-chip devices, thereby reducing component count and saving PCB real estate.

SaRonix xP vs. Third Overtone

Third overtone (3OT) crystal oscillators are used widely in high-speed applications. Third overtone oscillators are direct-output devices that use a piece of quartz that is manufactured to a thickness proportional to the precise operating frequency specified. The electrodes are printed on *opposite* sides of the crystal's surface, thereby inducing acoustic wave propagation through the bulk of the resonating element. The internal clock IC that converts the oscillations into a digital clock signal performs no additional frequency synthesis.

The primary advantage of 3OT oscillators is the optimization between jitter performance (short-term error), stability performance (long-term error), and cost. Third overtone technology achieves better phase noise/jitter performance than PLL+crystal and SAW technology, therefore improves overall system performance with lower BER. Third overtone technology also achieves better stability and lower cost than SAW technology. 3OT uses the three-dimensional *bulk* thickness of the quartz resonator element, thereby utilizing more mass as well as the 3-D crystalline structure to stabilize the oscillator's performance. Conversely, SAW (*surface acoustic wave*) technology only uses the 2-D surface of the resonator for acoustic wave propagation, therefore achieves a lower level of overall performance.

The primary disadvantage of third overtone oscillators is the "thinner" crystal element required for higher operating frequencies. As with any mechanical vibrating mass, to achieve higher operating frequencies, the thickness of the 3OT crystal is reduced. For example, a 60 MHz 3OT crystal is approximately 83 µm thick, whereas a 187.5 MHz 3OT crystal is approximately 27 µm thick. Not only are thinner crystal resonators more difficult to manufacture and thus higher cost, they are also more susceptible to elevated failure rates in the field. As such, 3OT becomes a less-practical technology for application faster than 100 MHz due to higher cost and lower reliability as a function of increasing frequency.

Owing to unique invention, the SaRonix xP Technology achieves higher operating frequencies, low jitter, lower unit cost, and better reliability/survivability than 3OT technology. The xP Technology utilizes a *thicker* crystal element than 3OT technology for a given output frequency, yet xP technology preserves the stability and jitter performance available with 3OT technology. **Table 1** compares the phase noise of the xP technology with the legacy technologies. The xP product achieves the lowest overall noise floor, and therefore exhibits less jitter than the other technologies, including 3OT, when computed in the application-sensitive 12 kHz to 20 MHz frequency band. Moreover, due to the thicker nature of the xP crystal, not only is the per-unit manufacturing cost less than that of 3OT oscillators (thicker crystals are easier to build and handle), but also the long-term reliability/survivability of xP oscillators is higher. A thicker quartz crystal is less prone to fracture, and also exhibits a lower overall equivalent series resistance (ESR) – the primary culprit behind oscillator startup failures. Overall, xP technology provides a more robust and cost-effective solution than traditional 3OT oscillators while preserving the desirable 3OT performance.

Table 1: SaRonix xP vs. 3OT Phase Noise @ 187.5 MHz

##	RMS Jitter, pS (computed in the 12 kHz to 20 MHz frequency band)	
	Pin 4	
	"noise-only" mode	"noise+spur" mode
XP Technology	0.2	0.2
3OT technology	0.31	0.31
SAW technology	0.82	Not tested
PLL technology (Femto)	1.44	1.44

SaRonix xP oscillators are designed to be footprint-compatible with industry-standard 3OT oscillators, thereby facilitating multi-source component and vendor strategies.

SaRonix xP vs. SAW

SAW oscillators are the third type of technology used in high-speed clocking applications. SAW resonators are constructed by printing the electrodes that induce oscillation on the *same* surface of the resonating element, thereby achieving oscillation in the form of surface waves that propagate between the electrodes. The electrodes are spaced and shaped to produce the desired frequency. The internal clock IC not only converts the oscillations into a digital clock signal, but also may perform frequency synthesis by dividing the resonator's actual frequency to synthesize the specified operating frequency.

The primary advantages of SAW oscillators are the improved reliability and higher "practical" operating frequencies than 3OT. In terms of jitter performance, SAW oscillators fall between that of xP/3OT and PLL; SAW technology does not achieve the same level of performance as xP or 3OT, but does achieve better jitter performance than PLL technology.

Although SAW oscillators offer improved reliability and moderate jitter performance, they exhibit distinct disadvantages with respect to the jitter performance, stability, and cost structure of oscillators constructed with xP technology.

With regards to jitter (short-term error), xP technology achieves superior performance over SAW technology. **Figure 3** shows the phase noise plot of a SaRonix xP oscillator compared with a

SAW oscillator, both operating at 212.5 MHz with LVPECL output for FibreChannel applications. High-speed applications, such as FibreChannel, 1/10 Gigabit Ethernet, SAS, and SONET/SDH, are sensitive to phase noise in the 12 kHz to 40 MHz frequency band. As the plot shows, the xP Technology achieves an overall lower level of noise in this application-critical band. In terms of computed phase jitter, xP oscillators achieve a 75% lower value, measuring 0.2 ps RMS compared with SAW oscillators measuring 0.8 ps RMS.

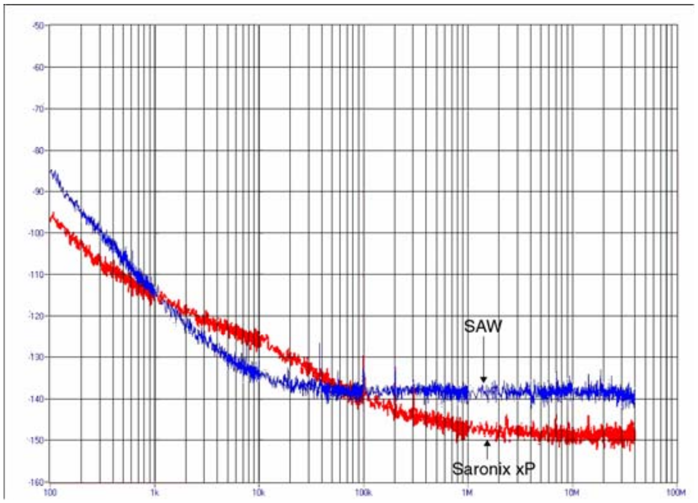

Figure 3: SaRonix xP vs. SAW Phase Noise @ 212.5 MHz

With regards to stability (long-term accuracy), xP technology achieves superior performance over SAW technology. **Figure 4** shows the frequency v. temperature curves of both technologies, obtained from a random sampling of xP and SAW devices. The xP oscillator exhibits a precise third-order temperature stability curve indicative of the benefits of the bulk crystalline structure of AT cut crystal. On the contrary, the SAW oscillator exhibits a less-precise second-order (parabolic) temperature coefficient indicative of SAW devices. For xP oscillators, the standard stability rating is ±50 ppM for commercial and industrial conditions, whereas SAW oscillators struggle to achieve this level of frequency accuracy. As such, SAW oscillators provide only marginal frequency accuracy and struggle to achieve tight stabilities required in many Ethernet and SONET/SDH applications (S*tability is defined as all-inclusive of any combination of rated operating conditions; stability includes initial frequency error @ RMT, error due to temperature change, aging, and shock, vibration, supply voltage & output loading changes within rating*).

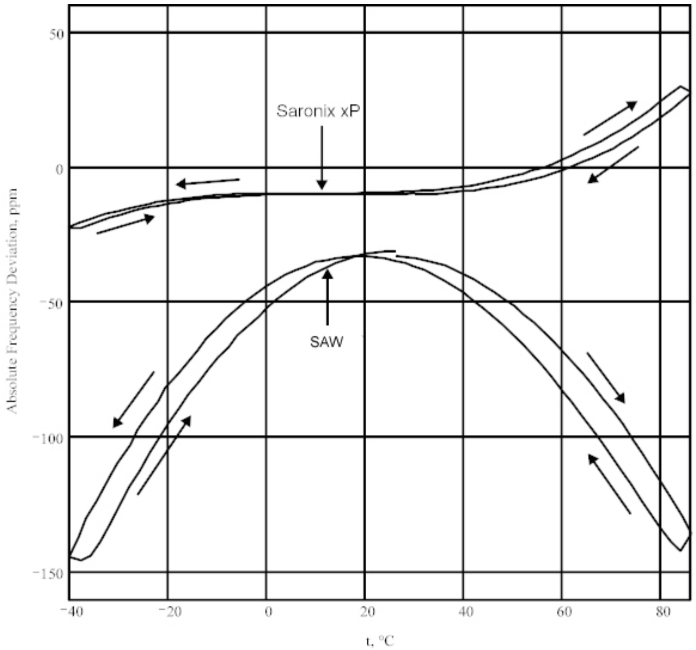

Figure 4: Frequency vs. Temperature of xP & SAW

The temperature characteristics of SAW technology may also lead to increased Bit Error Rates, thereby decreasing overall system performance. Due to the second-order temperature coefficient of SAW technology, a SAW oscillator's actual operating frequency changes rapidly over incremental temperature changes. Such a steep frequency v. temperature slope is a suspected root cause in increased BER when ambient temperature change or device self-heating occurs within a short timeframe. Indeed, a steep temperature slope may lead to increased events of instantaneous frequency "jumps" in a system, thereby causing instantaneous elevated BER. Such instantaneous BER spikes are often observed, yet difficult to reproduce in the laboratory or field. The steeply sloped, parabolic temperature curve of SAW oscillators is the likely root cause of instantaneous high-BER events. Meanwhile, xP oscillators exhibit a relatively shallow temperature slope when compared to SAW oscillators, thus xP technology is less prone than SAW to induce random, instantaneous high-BER events.

SaRonix xP oscillators are designed to be footprint-compatible with industry-standard SAW oscillators, thereby facilitating multi-source component and vendor strategies. In addition to the performance advantages of xP over SAW technology, the design of xP oscillators also achieves a lower per-unit cost structure than that of SAW oscillators.

Summary

The new xP Technology delivers a cost-effective, performance-enhanced clocking solution for use in high-speed networking, telecom, storage, and server applications. The xP oscillator outperforms PLL+crystal solutions by achieving an overall lower level of jitter and by offering a more compact, single-chip solution. The xP oscillator outperforms traditional third overtone (3OT) devices by achieving a lower overall manufacturing cost, enabling higher operating frequencies, and exhibiting improved long-term reliability/survivability inherent by design. Finally, the xP oscillator outperforms SAW oscillators by achieving lower overall jitter and phase noise, possessing a lower unit cost, and exhibiting a significantly better stability, leading to lower instances of instantaneous BER spikes. The SaRonix xP oscillators are available in industry-standard oscillator packages, which allow direct use in existing 3OT and SAW oscillator sockets.

For more information visit www.pericom.com/saronix

PH: 800-435-2336 FX: 408-435-1100
Pericom Semiconductor ▪ 3545 N. 1st Street ▪ San Jose, CA 95134