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- Newsletter
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- New Products
- Industry People
- Events Diary

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Technology Opinion Piece - The timing is right for crystal-free oscillators to replace Quartz

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The timing is right for crystal-free oscillators to replace Quartz

Sundar Vanchinathan, Senior Director, Integrated Device Technology

Introduction

As electronics technology continues to advance at a fast pace, the limitations of crystals and crystal oscillators as a practical approach to timing are being exposed. Higher frequencies and smaller form factors are forcing designers to use expensive, power hungry, smaller SMD crystal-based clocks that also often need additional circuitry to enable them to meet the performance requirements of the system. Furthermore, the proliferation of portable electronics equipment that is typically exposed to harsh operating conditions that include shock and vibration, has exposed the susceptibility of crystal oscillators to physical damage.

This article discusses the emergence of crystal- free oscillators, and in particular, CMOS-based parts as an alternative to traditional timing solutions.

Crystal oscillators hit their limits

Crystals are quite unique compared to other components used in electronic circuits in that the basis of their operation is essentially mechanical. The piezoelectric effect that causes the mechanical resonance of a vibrating quartz crystal was discovered as early as 1880, and the first quartz crystal oscillator was built and patented in 1917. While most other electronic components have continued to evolve rapidly to meet the demands of the latest products by shrinking in form factor, supporting high-speed operation, having reduced power consumption and becoming integrated with other devices, crystals and crystal oscillators have reached practical limits in many aspects of their evolution, construction and application.

As we share and exchange larger and more complex pieces of information, applications in both the consumer and industrial space are typified by ever-increasing data rates to meet demand for bandwidth. In order to meet this requirement, system designers are forced to use higher frequency oscillators. When using crystals alone, the maximum frequency of oscillation possible is in the region of 50 MHz; this is limited by the impracticality of manufacturing crystals to achieve higher frequencies. For frequencies over 50 MHz – which accounts for most current and next generation high speed applications – an inefficient approach that uses a crystal combined with a dedicated circuit to multiply the output frequency is required. While this approach allows the 'heartbeat' requirements of most products to be met, it also causes a number of other issues and challenges to become prevalent, the main one being power consumption which increases significantly as crystal oscillator output frequency rises. Multiplication of fundamental frequency to achieve higher frequencies also leads to increased jitter. These factors have made the emergence of power efficient 'crystal-free' all-silicon CMOS based oscillators that generate accurate frequencies on-chip without relying on a piezo-electric or mechanical resonator all the more welcome for designers.

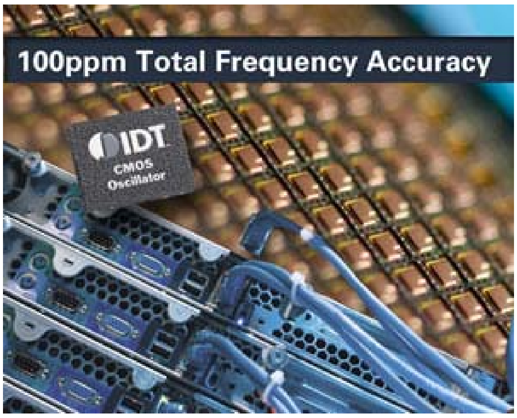
All-silicon CMOS oscillators such as Integrated Device Technology's IDT 3C Series have been developed to offer a viable alternative to conventional oscillators that also address the shortcomings and problems encountered when incorporating crystal-based devices into the latest fixed location and portable equipment applications. These include smart phones, laptops and tablet PCs, and datacom and connectivity interfaces such as 1 Gb Ethernet, SAS, SuperSpeed USB (USB 3.0) and PCI Express. By using a widely available and proven CMOS process, the cost, yield and reliability of the new devices is acceptable and can be well controlled. A programmable architecture allows flexible configuration to suit specific applications, the most critical of these options is the frequency of operation which is factory programmed and can be set at the exact desired level – this includes uncommon and application unique frequencies. In the case of the IDT 3C Series, parts can be chosen with operating frequencies ranging from 4 MHz to 200 MHz; this covers a wide range of applications in both the consumer, and computing and communications markets. Before designers can confidently embrace such a fundamentally different approach to timing, they must of course compare and understand the relative performance of the two approaches for a number of key criteria.

Power consumption

At lower frequencies, the power consumption of crystal oscillators is acceptable to designers. However, higher frequency devices – typically required for high data applications that are now commonplace – consume considerably larger, often prohibitive, amounts of power. For example, a typical crystal oscillator may draw several tens of mA. By comparison, a CMOS-based oscillator such as the IDT 3Cseries consumes only about2 mA (unloaded, typical) and just 200 nA in standby mode. In active mode, this level of performance represents a power saving versus crystal oscillators that of up to 90%

From both environmental and running cost standpoints, power consumption has become a critical specification that designers consider when selecting a component for their application, and that end users refer to when deciding which product to purchase. In the case of portable, battery powered equipment, this is heightened because overall low power consumption translates directly into longer periods between charging.

Size



The fact that a crystal oscillator requires a specific size and cut of crystal to give the required oscillation frequency means that there is a barrier when it comes to the potential to shrink the device package in terms of both footprint on the PCB and overall component height. Furthermore, the need for an additional circuit inside the package to achieve the desired frequency multiplication impacts overall package dimensions. Finally, in many designs, external capacitors and other passive components may be required in order to achieve stable performance of the oscillator. Typical package sizes for crystal oscillators are in the region of 5mm x 3mm with component height ranging from one to 1.5mm. Consideration must also be given to the PCB real estate required to accommodate any external passive components. All-silicon CMOS oscillators are completely self-contained requiring no external components; this helps to simplify design work for engineers and reduce both costs and the bill of materials. Device footprints are the same as those of standard crystal oscillators, however overall height is less at 0.5mm. This can be important to designers of small, portable pieces of equipment where there is competition for space with batteries, displays and user interfaces. Crucially, there is plenty of scope for further shrinking of package sizes for CMOS oscillators; indeed IDT is planning to offer a part measuring just 2mm x 1.6mm in the near future.

As designers of portable equipment are continually pressured to include more functionality in products with incredibly small overall dimensions, the potential to integrate CMOS oscillators into multi-chip modules (MCMs) can prove interesting where production volumes are significantly high. Including the oscillator in an MCM with the microprocessor and blocks such as flash memory can save space, cost (component and assembly) and power and enhance the reliability of the overall design.

Frequency error

Frequency error is an important specification for designers to consider. In some applications such as telecoms equipment only small frequency errors can be tolerated. For these applications specialized crystal oscillators with frequency errors of as low as 2ppm offer the only viable solution. However, for many applications, and in particular those in the consumer market, frequency errors of 100ppm are perfectly acceptable. This is the performance level of standard crystal oscillators and of currently available CMOS oscillators. Continued development of CMOS based parts looks set to see 50ppm parts on the market in the very near future that would make a wider range of end applications accessible to the technology.

When considering and comparing frequency error specifications it is important not to just look at the initial frequency tolerance. This is because in the case conventional crystals, additional errors need to be considered due to factors such as operating temperature (typically 50ppm), aging (typically 5ppm / year), and loading (up to 50ppm). In some cases this can mean that a part with a specified frequency tolerance of 50ppm does in practice, have an effective tolerance of up to 200ppm. CMOS oscillators are not affected by the factors described above, so long as they are operated within their designated operating temperature range. Therefore a 100ppm part should exhibit this frequency tolerance in operation, in an application.

Durability

The non-mechanical nature of CMOS oscillators means that they can be housed in low-cost conventional IC plastic packaging rather than more costly hermetically sealed ceramic packages that are needed for crystal-based devices. The proliferation of portable electronics equipment has placed increased importance on the durability of components contained within. As would be expected, CMOS oscillators offer high levels of durability and have semiconductor grade levels of shock and vibration resistance. Conversely, the electro-mechanical nature of crystal oscillators means that they can be susceptible to failure caused by shock and vibration experienced in normal use.

Noise and start-up

In applications such as high-end datacom, telecom and RF equipment there is often a requirement for very low phase jitter. In such cases, the performance of current generation of CMOS oscillators may not be good enough to allow replacement of crystal devices. However, because of the potential power and cost savings of switching to a CMOS part, designers should carefully consider whether their application could accept the alternative device. It is to be noted that next generation of CrystalFree oscillators are expected to break the 1ps phase jitter performance that is required to break into the high end Datacom and telecom applications. Susceptibility to increased jitter should also be considered carefully, with the metal can enclosures utilized by some crystals and crystal oscillators attracting noise and the associated performance and reliability issues. In certain applications this may necessitate the need for large ground planes to mitigate the problem. CMOS parts in their plastic enclosures do not suffer this problem and can therefore be used confidently in close proximity to areas of the circuit that may radiate EMI.

As the speed of modern electronic equipment increases and products spend much of their life in standby or sleep modes to conserve power, the issue of start-up time has gained greater importance. CMOS oscillators are able to move from an ultra-low power standby mode to a fully operational state in around just 100 µs; this is compared to approximately 10 ms for crystal oscillators.

Conclusion

With data rates increasing and a proliferation of portable, battery powered products with high levels of functionality continually coming to market, the need for high speed oscillators that are robust, have exceptional power efficiency, and are small in size, is significant. While crystal oscillators have served the electronics industry well for decades, aside from a limited number of high-end applications, the reasons for designers to consider switching to ‘crystal-free’ CMOS based timing solutions are compelling.

About IDT

Integrated Device Technology, Inc., the Analog and Digital Company™, develops system-level solutions that optimize its customers’ applications. IDT uses its market leadership in timing, serial switching and interfaces, and adds analog and system expertise to provide complete application-optimized, mixed-signal solutions for the communications, computing and consumer segments. Headquartered in San Jose, Calif., IDT has design, manufacturing and sales facilities throughout the world. IDT stock is traded on the NASDAQ Global Select Stock Market® under the symbol “IDTI.” Additional information about IDT is accessible at www.IDT.com.