WSB (RFIC) Sunday 08:00 – 17:00 BCEC Room 151AB
Current and Future Trends in Frequency Generation Circuits
Full-day workshop reviewed by RFIC.

Organizer(s):
Waleed Khalil, Intel; RFIC TPC.
Ahmed Helmy, Intel.

In order to adapt to the highly competitive IC market, chip suppliers are racing to reduce the total chip count by integrating many functionalities onto a single IC. However, one of the few elements that escaped this integration and remains to be off-chip is the timing source. In both wireless and wired systems, the reference source requires varying degrees of accuracy and stability over time and temperature. More often these accuracy requirements can only be met by using externally compensated reference sources such as (TCXOS) or (VCXOS), which occupy a large fraction of the board space. Hence a large emphasis is placed on eliminating these components by either integrating their functionality on- chip or replacing them with a much smaller footprint solution. This workshop will review various aspects in the design of stable and low phase noise oscillator circuits. Solutions that are gaining more popularity such as (DCXOS), MEMS and self-referenced oscillators will also be presented.

Speakers:
1. Michael M. Driscoll, Northrop Grumman
"Introduction to the Design and Performance of Quartz Crystal Oscillators"

This workshop presentation will focus on the analysis, design, performance, and evaluation of Crystal Oscillators. It will include a discussion of key oscillator performance parameters, including frequency stability and environmental stress sensitivity. Recent advances in crystal oscillator performance will also be described. At the conclusion of the presentation, attendees should be able to utilize, specify, and evaluate crystal oscillator design and performance criteria.

2. Michael McCorquodale, Mobius Microsystems
"Self-Referenced CMOS Oscillators"

The quartz crystal oscillator XO has been the de facto frequency source in electronic platforms for nearly 100 years. Through precise manufacturing and economies of scale, XOs have proven to be stable and low-cost frequency sources. However, XOs are referenced to macroscopic crystals (XTALs), which are not able to be integrated, thus often limiting device form-factor. Further, fundamental-mode XTALs scale only to modest frequencies. Addressing these limitations, several silicon-based CMOS and MEMS technologies have been developed in industry and university. This talk will focus on monolithic and self-referenced solid-state oscillators as frequency sources. It will be shown that with the advent of RF CMOS, self-referenced CMOS oscillators can be trimmed and compensated to realize frequency sources with unprecedented accuracy and stability. Further, the presented CMOS oscillator technology will be benchmarked against the incumbent XOs and emerging MEMS-referenced oscillators.

3. Ayman Ahmed, Si-Ware Systems
“Temperature Compensation Techniques of Crystal-less Reference Oscillators”

The recent advancements in MEMS and packaging technologies have triggered serious efforts to replace Crystal-based Oscillators with promises of smaller size and lower prices. Nonetheless, non-MEMS based approaches relying on integrated LC-tanks have emerged and are claiming performances appealing to consumer applications. Both approaches need to innovatively tackle two issues with minimum impact on phase noise and jitter: Frequency stability across temperature and frequency programmability. Solutions reported in literature and practiced by the author for these issues will be discussed and compared for both approaches. The use of SD Fractional-N PLLs for temperature compensation of MEMS oscillators will be discussed highlighting practical design issues and the impact of secondary effects on compensation accuracy and in turn on trimming strategy. The talk concludes with recent advances in using an LC-tank based Self-Compensated Oscillator (SCO) that achieves very promising performance.

4. Justin Black, Harmonic Devices Inc.
“Emerging Piezoelectric MEMS Resonators for Clock Synthesis”

This tutorial will review piezoelectric MEMS resonator and oscillator technologies, comparing these new devices to legacy quartz crystal and surface acoustic wave (SAW) solutions. Thin-film bulk acoustic wave, contour-mode, and piezo-on-SOI devices will be described. The discussion will include resonator fabrication, simulation, electrical and mechanical properties, oscillator results, and noise analysis. Market opportunities and commercialization challenges will also be described.

5. Eric Klumperink, University of Twente
“Recent Advances in Low-Jitter CMOS Clock Generation Stimulated by FoM Definitions”

The timing jitter and phase noise of clock generation circuits can usually be improved by admittance scaling at the cost of power consumption. To benchmark circuits and improve their jitter in a power efficient way, it makes sense to define a Figure of Merit (FoM) that normalizes for this admittance level scaling effect. We will discuss some recent ideas to advance the state-of-the-art in low jitter CMOS circuits, stimulated by the definition of such FoMs, more specifically: 1) A new relaxation oscillator topology which exploits a noise filtering technique to achieve 6dB better FoM than the best published relaxation oscillator. 2) A multi-phase clock generator, which can be implemented by a delay locked loop or a shift register. Using a jitter-power FoM, we shown that a shift register is preferred. 3) A new PLL exploiting a phase detector which uses sub-sampling of the VCO output by the reference clock to realize very low phase-noise within the PLL-loop bandwidth.

6. Ning Zhang and K. K. O, University of Florida
“Millimeter-wave Signal Generation in CMOS”

Complementary Metal Oxide Silicon (CMOS)technology is emerging as a viable integrated circuits technology for millimeter wave applications. A key component for millimeter wave systems is a signal generation circuit. This paper presents approaches for implementing the circuits including a mm-wave oscillator, frequency divider/prescaler, phase locked loop and frequency multiplier.

7. Gennady Feygin, Texas Instruments
“Integrated Digitally-Controlled Crystal Oscillators for Cellular Systems in Deep Sub-micron CMOS”

A reference clock generator is an essential building block of a modern RF communication system. This tutorial addresses system challenges inherent in designing Digitally Controlled Crystal Oscillator (DCXO) reference clock system for integrated GSM/EDGE cellular transceiver. Two principal DCXO architectures: Pierce and Colpitts are compared and relative advantages of each highlighted. Essential system parameters, including tuning range, tuning resolution, phase noise performance are analyzed. Issue that may prevent successful deployment in the field are also highlighted, including start-up issues in oscillators and interaction of amplitude and frequency control loops.

8. Mona M Hella, Rensselaer Polytechnic Institute
“Recent Advances in Multi-Standard Oscillator Design”

New standards such as software defined radios (SDR) and cognitive radios (CR) will reshape the wireless market in the next few years. The common features of such systems are frequency agility, whether wideband and/or multi-band operation and reconfigurability to adapt to different standards. In this talk, we will review recent advances in the design of multi-band oscillators. We will introduce two alternative techniques for multi-band oscillators that alleviate the need for direct switching of the tank parameters in traditional multi-band oscillators. First, we propose the use of double-tuned, double-driven transformers for the realization of dual band oscillators. We derive the conditions required to start oscillations for single-driven and double-driven, double-tuned transformers, explaining the nature of the band-switching mechanism. We also look at the relation between the coupling factor, frequency band separation, and quality factor at the two frequency bands from various perspectives. Second, we move the band switching mechanism from the tank to the oscillator core by introducing the new concept of band-limited negative resistance. We support our findings with measurement results from fabricated prototypes in silicon and GaAs technologies.