

# 29th Norchip Conference

13 November 2011 at 13.00-17.00, Lund, SWEDEN



## Norchip

## Integrated voltage-controlled oscillators (VCOs)

### Abstract

This tutorial lecture will go through the fundamentals of LC voltage-controlled oscillators (VCOs) integrated in CMOS processes, starting with basic linear and non-linear circuit analysis, and continuing with a rigorous yet intuitive time-variant theory of phase-noise capable of capturing the complex behavior of noise conversion into phase noise. Design for low power, low phase noise and large tuning range will be given the relevance it deserves, focusing primarily on the choice of inductor, switchable capacitors for discrete tuning, and varactors for continuous tuning.

The lecture will also include other key issues such as supply pushing, LDO-VCO co-design, routing/buffering the oscillator signals in large SoCs, and PLL-VCO co-design for fully integratable frequency synthesis. The goal is to give a thorough overview, easy to follow yet comprehensive and in touch with the latest significant research results (e.g. DCOs with extremely fine tuning steps for use in DPLLs), of one of the truly key blocks in today's and tomorrow's radios.

### Outline:

- 13.00 Introduction and linear analysis of harmonic oscillators
- 13.30 Non-linear analysis of popular harmonic oscillators
- 14.00 Passive components; frequency tuning
- 14.30 Coffee break
- 14.50 Introduction to phase noise; time-variant analysis
- 15.20 Phase noise in popular harmonic oscillators
- 16.20 Interface circuits (voltage regulators, buffers)
- 16.50 Conclusions

### References:

- [1] A. Hajimiri and T. H. Lee, "A general theory of phase noise in electrical oscillators," *IEEE J. Solid-State Circuits*, vol. 33, no. 2, pp. 179–194, Feb. 1998.
- [2] H. Sjöland, "Improved switched tuning of differential CMOS VCOs," *IEEE Trans. Circuits Syst. II*, vol. 49, no. 5, pp. 352–355, May 2002.
- [3] P. Andreani and A. Fard, "More on the  $1/f^2$  phase noise performance of CMOS differential-pair LC-tank oscillators," *IEEE J. Solid-State Circuits*, vol. 41, no. 12, pp. 2703–2712, Dec. 2006.
- [4] A. Mazzanti and P. Andreani, "Class-C harmonic CMOS VCOs, with a general result on phase noise," *IEEE J. Solid-State Circuits*, vol. 43, no. 12, pp. 2716–2729, Dec. 2008.
- [5] P. Andreani *et al.*, "A TX VCO for WCDMA/EDGE in 90 nm RF CMOS," *IEEE J. Solid-State Circuits*, vol. 46, no. 7, pp. 1618–1626, July 2011.

**Pietro Andreani** received the M.S.E.E. degree from the University of Pisa, Italy, in 1988, and the Ph.D. degree from Lund University, Sweden, in 1999. Between 2001 and 2007, he was chair professor at the Center for Physical Electronics, Technical University of Denmark. Since 2007, he has been associate professor at the dept. of Electrical and Information Technology (EIT), Lund University, working in analog/mixed-mode/RF IC design; he is also a part-time IC designer at ST-Ericsson in Lund. He is a TPC member of both ISSCC and ESSCIRC. He has authored several papers on harmonic oscillators and phase noise.

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