RF CMOS Oscillators for Modern Wireless Applications

RIVER PUBLISHERS SERIES IN CIRCUITS AND SYSTEMS

Indexing: All books published in this series are submitted to the Web of Science Book Citation Index (BkCI), to SCOPUS, to CrossRef and to Google Scholar for evaluation and indexing.

The "River Publishers Series in Circuits & Systems" is a series of comprehensive academic and professional books which focus on theory and applications of Circuit and Systems. This includes analog and digital integrated circuits, memory technologies, system-on-chip and processor design. The series also includes books on electronic design automation and design methodology, as well as computer aided design tools.

Books published in the series include research monographs, edited volumes, handbooks and textbooks. The books provide professionals, researchers, educators, and advanced students in the field with an invaluable insight into the latest research and developments.

Topics covered in the series include, but are by no means restricted to the following:

- Analog Integrated Circuits
- Digital Integrated Circuits
- Data Converters
- Processor Architecures
- System-on-Chip
- Memory Design
- Electronic Design Automation

For a list of other books in this series, visit www.riverpublishers.com

RF CMOS Oscillators for Modern Wireless Applications

Masoud Babaie

Delft University of Technology
The Netherlands

Mina Shahmohammadi

Catena
The Netherlands

Robert Bogdan Staszewski

University College Dublin
Ireland

River Publishers

Published, sold and distributed by:
River Publishers
Alsbjergvej 10
9260 Gistrup
Denmark

River Publishers
Lange Geer 44
2611 PW Delft
The Netherlands

Tel.: +45369953197
www.riverpublishers.com

ISBN: 978-87-93609-49-5 (Hardback)
978-87-93609-48-8 (Ebook)

Printed on acid-free paper.

Contents

Preface

The steady growth of cellular and wireless communications motivates researchers to improve the performance of the systems, overcome the limitations and face new the challenges. One of the key blocks in a wireless radio is the RF oscillator which its purity limits the radio performance. The oscillator's phase noise in a transmit chain results in power leakage into adjacent channels. In the receive chain, the downconversion of a large interferer with noisy local oscillator (LO) cause reciprocal mixing. Furthermore, in orthogonal frequency-division multiplexing (OFDM) systems, the phase noise leads to inter carrier interference and a degradation in the digital communication bit error rate. The trade-off between oscillator's phase noise and its power consumption introduce a challenge for oscillator designers.

The main focus of this book is on the design and implementation of RF oscillators for wireless (mostly cellular) applications. Each oscillator that is introduced in these chapters tackles an obstacle in RF designs, such as low $1/f^2$ or low $1/f^3$ phase noise requirements, low voltage, low power requirements, and wide tuning range requirements.

Chapter 1 discusses how a transceiver performance can be limited by an oscillator characteristics. It also reviews how technology scaling affects an oscillator's performance.

Chapter 2 is a reminder how circuit noise up-converts to phase noise in an oscillator, and then briefly introduces and compares different LC oscillator structures.

In Chapter 3 we introduce a class-F_3 oscillator topology which demonstrates an improved phase noise performance by enforcing a pseudo-square voltage waveform around the LC tank by increasing the third harmonic of the fundamental oscillation voltage through an additional impedance peak. Furthermore, a comprehensive study of circuit-to-phase-noise conversion mechanisms of different classes of RF oscillator is presented.

In Chapter 4, we elaborate on a design and implementation of class-F_2 oscillators. The main idea is to enforce a clipped voltage waveform around the LC tank by increasing the second-harmonic of fundamental oscillation voltage through an additional impedance peak, thus giving rise to a class-F_2 operation. This oscillator specifically addresses the ultra-low phase noise design space while maintaining high power efficiency. Extensive experimental results are also presented at the end of this chapter.

Excited by a harmonically rich tank current, a typical oscillation voltage waveform is observed to have asymmetric rise and fall times. This results in an effective impulse sensitivity function (ISF) of a non-zero dc value, which facilitates the flicker (1/f) noise up-conversion into the oscillator's $1/f^3$ phase noise. Chapter 5 elaborates a method to reduce a 1/f noise up-conversion in voltage-biased RF oscillators.

Chapter 6 introduces and analyzes in detail an oscillator with switching current sources to reduce supply voltage and power without sacrificing its phase noise and startup margins. This oscillator is specifically addressed IoT application constraints.

In Chapter 7 a method to broaden a tuning range of an LC-tank oscillator without sacrificing its area is presented. The extra tuning range is achieved by forcing a strongly coupled transformer-based tank into a common-mode resonance at a much higher frequency than in its main differential-mode oscillation. The oscillator employs separate active circuits to excite each mode but it shares the same tank, which largely dominates the core area but is on par with similar single-core designs.

Chapter 8 presents a design guide to estimate the time dependent dielectric beak down of any analog circuit with evaluating life time of class-F oscillators as an example.

List of Figures

List of Tables

List of Abbreviations

4G	Fourth generation
5G	Fifth generation
AM	Amplitude modulation
BEOL	Back-end-of-line
BTS	Base station
BLE	Bluetooth Low Energy
CMP	Chemical-mechanical polishing
CMOS	Complementary metal-oxide-semiconductor
DCO	Digitally controlled oscillator
DT	Direct quantum-mechanical tunneling
FoM	Figure of merit
FinFET	Fin Field-effect transistor
FN	Fowler–Nordheim
GSM	Global system for mobile
ISF	Impulse sensitivity function
IoT	Internet-of-Things
KCL	Kirchhoff's current law
LTV	Linear time variant
LO	Local oscillator
MoM	Metal-oxide-metal
MOS	Metal-oxide-semiconductor
NBTI	Negative bias temperature instability
OFDM	Orthogonal Frequency-Division Multiplexing
PER	Packet error rate
PLL	Phase lock loop
PM	Phase modulation
PN	Phase noise
PA	Power amplifier
PVT	Process-voltage-temperature
Q-factor	Quality factor
RF	Radio frequency

SNR	Signal-to-noise ratio
SoC	System-on-chips
TDDB	Time-dependent dielectric breakdown
TR	Tuning range
ULP	Ultra-low power
UMTS	Universal mobile telecommunication system
VCO	Voltage control oscillator