Integration of Passive RF Front End Components in SoCs

Examining the most important key developments in highly integrated wireless RF front ends, this book describes and evaluates both active and passive solutions for on-chip high-Q filtering, and explores M-phase filters in depth.

An accessible step-by-step approach is used to introduce everything an RF designer needs to know about these filters, including their various forms, principles of operation, and their performance against implementation-related imperfections. Real-world examples are described in depth, and detailed mathematical analyses demonstrate the practical quantification of pertinent circuit parameters.

Hooman Darabi is a Senior Technical Director and Fellow of Broadcom Corporation, California, and an Adjunct Professor at the University of California, Irvine. He is an IEEE Solid State Circuits Society distinguished lecturer.

Ahmad Mirzaei is a Senior Principal Scientist within the Mobile and Wireless division of Broadcom Corporation, California. His research interests involve analog and RF IC design for wireless communications.

Cambridge University Press
978-0-521-11126-3 - Integration of Passive RF Front End Components in SoCs
Hooman Darabi and Ahmad Mirzaei
Frontmatter
More information

Integration of Passive RF Front End Components in SoCs

HOOMAN DARABI
Broadcom Corporation

AHMAD MIRZAEI
Broadcom Corporation

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town,
Singapore, São Paulo, Delhi, Mexico City

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521111263

First published 2013

Printed and Bound in the United Kingdom by the MPG Books Group

A catalogue record for this publication is available from the British Library

ISBN 978-0-521-11126-3 Hardback

Contents

Notation

2G	second-generation mobile telephone technology
2.5G	second-generation mobile telephone technology
3G	third-generation mobile technology
3GPP	third-generation partnership project
ADC	analog-to-digital converter
AGC	automatic gain control
AND	logic gate for AND operation
BB	baseband
BPF	bandpass filter
CMOS	complementary metal oxide semiconductor
DAC	digital-to-analog converter
DC	0 Hz frequency
DFF	delay/data flip-flop
DSP	digital signal processor
EDGE	enhanced data for GSM evolution
FDD	frequency division duplex
FTBPF	frequency-translated bandpass filter
GHz	gigahertz
GPRS	general packet radio service
GPS	global positioning system
GSM	global system for mobile communications
HSPA	high-speed packet access
Hz	hertz
IC	integrated circuit
IF	intermediate frequency
IIP2	second-order intercept point
IIP3	third-order intercept point
IM2	second-order intermodulation
IM3	third-order intermodulation
KCL	Kirchhoff's current law
kHz	kilohertz
KVL	Kirchhoff's voltage law
LC	inductor, capacitor
LNA	low noise amplifier

LO	local oscillator
LOFT	local oscillator feedthrough
LPCC	leadless plastic chip carrier
LPF	low-pass filter
LTE	long-term evolution (3GPP)
LTI	linear time-invariant
LTV	linear time-variant
MHz	megahertz
MOS	metal oxide semiconductor
MX	mixer
NF	noise figure
pac	AC simulation after pss in SpectreRF
PAR	peak-to-average ratio
PCS	personal communication service
PLL	phase-locked loop
PSD	power spectral density
pss	periodic steady state in SpectreRF
Q	quality factor
QOSC	quadrature oscillator
RC	resistor, capacitor
RF	radio frequency
RFIC	radio frequency integrated circuit
RLC	resistor, inductor, capacitor
RLCM	resistor, inductor, capacitor, mutual inductance
RSSI	received signal strength indication
RX	receiver
SAW	surface acoustic wave
SC	switched capacitor
SDR	software-defined radio
SNR	signal-to-noise ratio
SoC	system on chip
TDD	time division duplex
TIA	transimpedance amplifier
TX	transmitter
VCO	voltage-controlled oscillator
WCDMA	wideband code division multiple access
WLAN	wireless local area network
WPAN	wireless personal area network

Cambridge University Press
978-0-521-11126-3 - Integration of Passive RF Front End Components in SoCs
Hooman Darabi and Ahmad Mirzaei
Frontmatter
More information

Preface

Designing less expensive RF wireless transceivers that can operate effectively and efficiently in the crowded wireless spectrum is a major challenge that must be met by today's designers. To reduce silicon costs, the chip dies must be as small as possible. To reduce the cost and size of batteries in mobile wireless devices, the amount of power consumed by the chip must be as little as possible. External components such as filters and their matching components, which are bulky and expensive, must be integrated on the chip to the greatest extent possible.

To address the issue of operating effectively in a crowded wireless spectrum, cognitive radios have been introduced. Cognitive radios are smart devices that can search for any available spectrum (even ones that are outside of what is specified by the standard) and take advantage of that free spectrum. Additionally, over the last decade, researchers have been exploring the possibility of using a universal radio that can be programmed and reconfigured through software to operate on any band, channel bandwidth, and modulation scheme. Such a universal radio is called a software-defined radio (SDR).

For a wireless device to support SDR, it must be capable of broadband operation, which raises a few unique challenges. The receiver of such a broadband device is open to any in-band or out-of-band interferences and must be able to tolerate them while maintaining good sensitivity. To overcome this challenge, narrowband receivers traditionally use an external sharp filter, typically a surface acoustic wave (SAW) filter, to attenuate the out-of-band blockers. This external SAW filter and its matching components, however, add to the cost and form factor, especially for multiband applications such as LTE, which can support up to 10 bands. Basically, one SAW filter plus its matching components is needed for every single receive band of operation. In a SAW-less receiver, however, these external components are eliminated and replaced with some sort of on-chip filtering. Due to the poor quality factor of on-chip inductors, these external devices cannot be implemented with on-chip passive networks. Also, on-chip active filters with high quality factors generally suffer from poor noise and linearity performance, and their center frequencies drastically drift over process, voltage, and temperature variations. Therefore, to integrate these filters, the designers must devise highly linear and low-noise filtering solutions with center frequencies that can be controlled conveniently. This book discusses techniques that can be used to design and implement SAW-less broadband receivers with sharp on-chip filters, the center frequencies of which are precisely controlled by a clock frequency.

The book consists of eight chapters. Chapter 1 gives a brief overview of several circuit design techniques proposed to enable highly programmable and tunable front-end filters integrated with the rest of the CMOS RF IC. In this chapter, the system-level requirements of the radio front ends are discussed. The main focus is on cellular applications, which are the most challenging realization of an SDR or a cognitive radio.

Chapter 2 discusses active blocker-cancellation techniques and shows how these techniques enable SAW-less receivers.

Chapters 3 through 5 introduce new on-chip filters (M-phase filters) that outperform all other types of filters in terms of linearity, noise, and power consumption. The remainder of the book is dedicated to learning and understanding these M-phase filters with all possible formats. The operation of these M-phase filters is founded on the impedance transformation property of passive mixers.

Chapter 6 describes a highly integrated superheterodyne CMOS receiver that uses M-phase filters to deal with blockers. Chapter 7 addresses the robustness of the M-phase filters against various imperfections. Chapter 8 describes how the dual of the conventional M-phase filter can offer sharp filtering for low-impedance nodes.

We are deeply grateful to Richard Carter and Raphael Alden for proofreading and editing the book and for their fruitful comments. Many useful technical discussions with Mohyee Mikhemar and David Murphy are greatly appreciated. We would also like to thank Julie Lancashire and Elizabeth Horne of Cambridge University Press for their support.