

SpringerBriefs in Electrical and Computer Engineering

For further volumes:
<http://www.springer.com/series/10059>

Samantha Yoder • Mohammed Ismail
Waleed Khalil

VCO-Based Quantizers Using Frequency-to-Digital and Time-to-Digital Converters

 Springer

Samantha Yoder
The ElectroScience Laboratory
The Ohio State University
Columbus, OH 43212, USA
yoder.164@osu.edu

Mohammed Ismail
Department of Electrical
and Computer Engineering
The Ohio State University
Columbus, OH 43210-1272, USA
ismail@ece.osu.edu

Waleed Khalil
The ElectroScience Laboratory
The Ohio State University
Columbus, OH 43212, USA
khalil@ece.osu.edu

ISSN 2191-8112 e-ISSN 2191-8120
ISBN 978-1-4419-9721-0 e-ISBN 978-1-4419-9722-7
DOI 10.1007/978-1-4419-9722-7
Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2011934750

© Springer Science+Business Media, LLC 2011

All rights reserved. This work may not be translated or copied in whole or in part without the written permission of the publisher (Springer Science+Business Media, LLC, 233 Spring Street, New York, NY 10013, USA), except for brief excerpts in connection with reviews or scholarly analysis. Use in connection with any form of information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed is forbidden.

The use in this publication of trade names, trademarks, service marks, and similar terms, even if they are not identified as such, is not to be taken as an expression of opinion as to whether or not they are subject to proprietary rights.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Traditional analog-to-digital converters (ADCs) face many design challenges as technology scales. A few of these challenges are (1) voltage dynamic range decreases making it difficult to accurately quantize in the voltage domain (2) architecture contains many analog components which are challenging to design in deep submicron complementary metal oxide semiconductor (CMOS) processes. Voltage-controlled oscillator (VCO)-based ADCs are gaining popularity due to the highly digital architecture and improved timing resolution in deep submicron CMOS processes.

This book presents a theoretical and modeling approach to understanding the VCO-based quantizer. Two digital time quantizer architectures are reviewed: one using a frequency-to-digital converter (FDC) and the other using a time-to-digital converter (TDC). The TDC architecture is new to the application of the VCO-based quantizer.

Chapter 1 provides an introduction including the motivation for this topic, background on the subject, and goals of this work.

Chapter 2 provides an introduction and theoretical analysis of the FDC and TDC VCO-based quantizer. Theoretical equations are developed to determine the resolution of the quantizers and verified through a VerilogA model.

Chapter 3 provides modeling and analysis of circuit nonidealities of the VCO-based quantizer. These nonidealities are added to the VerilogA model and theoretical equations derived to verify the effects on both the FDC and TDC architecture.

Chapter 4 provides some final thoughts and analysis on the FDC and TDC VCO-based quantizer.

Chapter 5 concludes the book.

Columbus, OH, USA

Samantha Yoder
Mohammed Ismail
Waleed Khalil

Contents

1	Introduction	1
1.1	Motivation	1
1.2	Background	1
1.3	Goals of this Work	7
1.4	Organization	7
	References	8
2	VCO-Based Quantizer	9
2.1	VCO Operation	9
2.2	FDC VCO-Based Quantizer	11
2.2.1	Linear Modeling and Analysis	13
2.2.2	Model Verification Using VerilogA	16
2.3	TDC VCO-Based Quantizer	17
2.3.1	Linear Modeling and Analysis	20
2.3.2	Model Verification Using VerilogA	23
2.4	FDC vs. TDC Architecture	25
2.5	Summary	28
	References	29
3	Limitations of the VCO-Based Quantizer	31
3.1	VCO Nonlinearity	31
3.1.1	Modeling and Analysis	31
3.1.2	Verification: FDC vs. TDC Architecture	34
3.2	VCO Phase Noise	36
3.2.1	Modeling and Analysis	36
3.2.2	Verification: FDC vs. TDC Architecture	43
3.3	Sampling Clock Jitter	44
3.3.1	Modeling and Analysis	45
3.3.2	Verification: FDC vs. TDC Architecture	46
3.4	Summary	48
	References	49

- 4 Further Analyses: FDC vs. TDC** 51
 - 4.1 FDC/TDC Circuit Requirements 51
 - 4.2 Two-Tone Test..... 52
 - 4.3 Final Thoughts 53
 - References..... 54
- 5 Conclusions**..... 55

Abbreviations

ADC	Analog-to-digital converter
CMOS	Complementary metal oxide semiconductor
CP	Charge pump
DAC	Digital-to-analog converter
DEM	Dynamic element matching
DFF	D flip-flop
$\Delta\Sigma$	Delta-sigma
FDC	Frequency-to-digital converter
FFT	Fast Fourier transform
MB	Multibit
NTF	Noise transfer function
OSR	Oversampling ratio
PLL	Phase-locked loop
PSD	Power spectral density
PWM	Pulse width modulation
RVCO	Ring VCO
SNR	Signal-to-noise ratio
SNDR	Signal-to-noise plus distortion ratio
STF	Signal transfer function
TDC	Time-to-digital converter
THD	Total harmonic distortion
VCO	Voltage-controlled oscillator

