CONTINUOUS-TIME SIGMA-DELTA MODULATION FOR A/D CONVERSION IN RADIO RECEIVERS

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CONTINUOUS-TIME SIGMA-DELTA MODULATION FOR A/D CONVERSION IN RADIO RECEIVERS

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List of abbreviations

A/D	analog-to-digital
ADC	analog-to-digital converter
AGC	automatic gain control
AM	amplitude modulation
BER	bit error rate
BW	bandwidth
CLK	clock
CM	cross-modulation
CT	continuous-time
D/A	digital-to-analog
DAC	digital-to-analog converter
DEM	dynamic element matching
DLL	delay-locked loop
DR	dynamic range
DSP	digital signal processor
EXOR	exclusive-or
FFT	fast fourier transform
FM	frequency modulation
FOM	figure-of-merit
GMSK	gaussian minimum-shift-keying
HD	harmonic distortion
I	in-phase
IF	intermediate frequency
IM	intermodulation distortion
IP	intercept point
IR	image rejection
LNA	low-noise amplifier
LO	local oscillator
LSB	least significant bit
NTF	noise transfer function
NZIF	near-zero-IF
OPAMP	operational amplifier
OSR	oversampling ratio
P	power

PLL	phase-locked loop
Q	quadrature-phase
RF	radio frequency
RTZ	return-to-zero
SAW	surface acoustic wave
STF	signal transfer function
ΣΔ	sigma-delta
SFDR	spurious-free dynamic range
SINAD	signal-to-noise-and-distortion
SNDR	signal-to-noise-and-distortion ratio
SNR	signal-to-noise ratio
SQNR	signal-to-quantization-noise ratio
V/I	voltage-to-current
ZIF	zero-IF

List of symbols

Δ	relative error	-
Δa	relative gain error	-
$\Delta\varphi$	phase error	rad,°
Δ_q	quantization step size	-
δ	duty cycle	-
φ	phase	rad,°
κ	quantizer gain	-
κ_s	minimum (large signal) stable quantizer gain	-
μ	charge carrier mobility	cm^2/Vs
π	pi, 3.141593	-
θ	quantizer phase	°
σ_j	standard deviation	-
τ	time constant	s
ω_u	unity gain frequency	rad/s
ω_z	zero frequency	rad/s
A	DC gain	-
a_n	n^{th} butterworth coefficient	-
b_n	n^{th} feedback coefficient	-
C	symbol for capacitor	F
C_{db}	drain-bulk capacitor	F
C_{ds}	drain-source capacitor	F
C_{gd}	gate-drain capacitor	F
C_{gs}	gate-source capacitor	F
C_i	integration capacitor	F
C_{ox}	normalized oxide capacitance	F
c_n	n^{th} feedforward coefficient	-
d_n	n^{th} local feedback coefficient	-
e	quantization error	-
f,ω	frequency	Hz, rad/s
f_b	bandwidth	Hz
f_{LO}	local oscillator frequency	Hz
f_s	sampling frequency	Hz
g_m	transconductance	S
$H(s)$	loopfilter transfer function	-
I_b	bias current	A

I_{os}	offset current	A
I_{dac}	DAC current	A
i	small signal current	A
i_{dac}	transient DAC current	A
i_{in}	transient input current	A
i_r	residue current	A
j	complex operator	-
k	Boltzmanns' constant, $1.3805 \cdot 10^{-23}$	J/K
L	channel length of MOS transistor	μm
m	oversampling ratio	-
Nj	jitter power	W
N_q	quantization noise power	W
N_{th}	thermal noise power	W
P	power	W
P_{in}	input power	W
Q	charge	C
q	quantization level	-
RTZ	return-to-zero duty cycle	-
R_{dac}	DAC resistor	Ω
R_{in}	input resistor	Ω
R_L	load resistor	Ω
R_s	degeneration resistor	Ω
r_{on}	switch ON-impedance	Ω
s	Laplace operator	rad/s
T	temperature	K
T_s	sampling period	s
t	time	s
V_{DD}	positive supply voltage of MOS circuits	V
V_{SS}	negative supply voltage of MOS circuits	V
V_{dac}	DAC voltage	V
v_{dac}	transient DAC voltage	V
V_{ds}	drain-source voltage	V
V_g	gate-to-ground voltage of MOS transistor	V
V_{gs}	gate-source voltage	V
$V_{gs,eff}$	effective gate-source voltage	V
V_{in}	input voltage	V
v_{in}	transient input voltage	V
V_{os}	offset voltage	V
v_r	residue voltage	V
V_{Th}	threshold voltage	V
W	channel width of MOS transistor	μm

Preface

This book describes the theory, design and realizations of continuous-time ΣΔ modulators for analog-to-digital conversion in radio receivers. The challenge of the work is the design of a ΣΔ modulator with high linearity, large dynamic range and strong image rejection capabilities. With such an A/D converter, requirements for a receiver architecture in terms of selectivity and sensitivity can be relaxed, resulting in a cheaper system with a higher level of integration.

Important trends in the receiver design for wireless portable applications are: smaller product sizes, cheaper products and longer stand-by times. Products can be made smaller and cheaper by increasing the level of integration. This means on-chip integration of external components, such as inductors and filters. Herein, an important role can be played by the A/D converter. Shifting the A/D converter towards the antenna side of the receiver, allows more digital integration of (external) analog functions on a single digital chip. However, this requires an A/D converter with high linearity, dynamic range, bandwidth and image rejection capabilities.

In chapter 2, it will be shown that the required performance of the ADC depends very much on its place in the receiver architecture. Single-bit continuous-time ΣΔ modulation is a good technique for A/D conversion in receivers, as it incorporates inherent anti-aliasing filtering, excellent linearity performance, and low-power capability. All these performance aspects are particularly important in battery-powered receivers. The main performance parameters are described and a figure-of-merit is presented that is used for comparison between different designs.

In chapter 3, the theory of higher-order continuous-time ΣΔ modulation is described. Important aspects, determining the performance of a continuous-time ΣΔ modulator, are quantization noise, DC tones, intersymbol interference, clock jitter, and aliasing. The design of higher-order filters is described, with Butterworth and inverse-Chebyshev filter characteristics. With the availability of quadrature signals in a radio receiver, the theory of quadrature ΣΔ modulation is treated as well.

Chip realizations are described in chapter 4 and chapter 5. Chapter 4 describes the design of a ΣΔ modulator with integrated mixer. The key features of this IF-tobaseband A/D converter are the high linearity and low-power consumption. In chapter 5 the design of a quadrature ΣΔ modulator with a data-dependent dynamic element matching circuit is shown. Measurements on this A/D converter show a high image rejection of 63 dB typically.

In the last chapter the main conclusions are summarized. The performance of the prototype test chips that have been described in this book are compared with other state-of-the-art test designs from literature.

The authors wish the reader a pleasant time in investigating the interesting aspects of continuous-time ΣΔ modulation for A/D conversion in radio receivers.

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