Capacitance-to-Digital Converter for Lab-on-Chip Digital Microfluidics System and An Ultra-low Power SAR ADC with Effective Calibration

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

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Abstract

CAPACITANCE-TO-DIGITAL CONVERTER FOR LAB-ON-CHIP DIGITAL MICROFLUIDICS SYSTEMS AND ULTRA-LOW POWER SAR ADC WITH EFFECTIVE CALIBRATION

by XIAO YAN JIE

Thesis Supervisor: Prof. Pui In Mak
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Master of Science in Electrical and Electronics Engineering

Two parts have been presented in this thesis.

The first part presents an ultra-low-power capacitance-to-digital converter (CDC) for digital microfluidics systems that demand a wide capacitive sensing range. It is structured with a switched-capacitor capacitance-to-current front-end interface, followed by a differential current-mode successive approximation register (SAR) analog-to-digital converter (ADC). By using subthreshold-biased transistors, the differential current-mode SAR ADC significantly saves power and reduces sensitivity to supply voltage and clock variation. The 8-bit 1-kS/s CDC designed in 0.35-μm CMOS exhibits a capacitance sensing range from 1.5 to 20 pF while consuming a total power of 0.8 μW. The ENOB of the current SAR ADC is 7.46.

The second part presents an ultra-low power 13 bits resolution SAR ADC with effective calibration system used in bio-potential acquisition system, designed in 0.18 μm CMOS. The optimized switching methods can save lots of power consumption, and a dual-supply voltage with level-shifter theory applied in the SAR logic part effectively cut down the power consumption in digital part. Calibration is necessary for high resolution SAR ADC, especially the split architecture, two steps calibration are operated in this proposed work and stored the measured data of capacitor both parasitic and mismatch error by the calibration CADCs and DFFs. The total power of SAR ADC in conversion is only 97.6nW, 11.8 ENOB with the FoM of 27.4 fJ/c.s in post-simulation, the core area of the proposed work is only occupied 0.094mm^2.

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The deepest love and gracious to my father, I love him forever.

LIST OF ABBREVIATIONS

ADC: Analog-to-Digital Converter

CDC: Capacitance-to-Digital Converter

CM: Current Mode

CVC: Capacitance-to-Voltage Converter

DAC: Digital-to-Analog Converter

DC: Direct Current

DNL: Differential Nonlinearity

ECG: Electrocardiogram

EEG: Electroencephalogram

ENOB: Effective Number of Bits

EMG: Electromyogram

EWOD: Electro-Wetting On Dielectric

FOM: Figure Of Merit

INL: Integral nonlinearity

LSB: Least Significant Bit

MIM: Metal Injection Metal

MOS: Metal Oxide Semiconductor

MSB: Most Significant Bit

Mux: Multiplexier

NMOS: N-Channel Metal Oxide Semiconductor

OTA: Operational Transconductance Amplifier

PMOS: P-Channel Metal Oxide Semiconductor

RC: Resistor-Capacitor

SAR: Successive Approximation Register

SC: Switched-Capacitor

SNR: Signal to Noise Ratio

SOC: System On Chip

TI: Time-Interleaved

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TABLE OF CONTENTS

Abstract I
Acknowledgments III
List of Abbreviations V
Table of Contents VII
List of Figures IX
List of Tables XI
Chapter 1: Introduction 1
1.1 Capacitance-to-Digital Converter for Lab-on-chip Digital Microfluidics Systems 1
1.2 Ultra-Low Power SAR ADC With Calibration Techqique 4
1.3 Motivations 9
1.4 Research Objectives 9
1.5 Thesis Organization 10
Chapter 2: Capacitance-to-Digital Converter For Lab-on-Chip Digital Microfluidics Systems 11
2.1 System Design Consideration and Analysis 11
2.1.1System Configuration 11
2.1.2 Forefront Capacitance-to-Current Interface. 12
2.1.3 Current-Mode Differential SAR ADC 18
2.2 Simulation results 22
2.3 Conclusions 26
Chapter 3: Ultra-Low Power SAR ADC with Calibration Technique 27
3.1 Circuit Design Consideration and Analysis 27
3.1.1 Circuit Configuration 27
3.1.2 Operation Process and Conversion Power Estimation 31
3.1.3 The Level-Shifter of The SAR Logic 33

3.1.4 Switch Design 34
3.1.5 Comparator Circuit Design 35
3.2 SAR ADC Calibration 36
3.2.1 Calibration Characteristics and Necessary Analysis 36
3.2.2 Bridge Capacitor Calibration 38
3.2.3 The Upper 5 bits Calibration 40
3.2.4 Calibration Circuit Logic Design 43
3.3 Layout 47
3.4 Post-Simulation Results 48
3.5 Conclusions 52
Chapter 4: Conclusions 52
4.1 Summary 53
4.2 Future Work 54
References 55
VITA 60

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LIST OF FIGURES

Figure 1.1 Slide view of an EWOD digital microfluidics system..... 2

Figure 1.2 Block diagram of general purpose biopotential acquisition system (1 channel) 5

Figure 1.3 Categories of ADC architectures based on the power consumption, resolution and speed of ADCs. 6

Figure 1.4 Amplitude and spectral range of general biopotential signals 8

Figure 2.1 The block diagram of the proposed CDC. 11

Figure 2.2 The capacitance-to-current interface circuit..... 13

Figure 2.3 The operation timing diagram of the interface circuit. 14

Figure 2.4 The drain voltage variation of M1a and M2a during charging of Cr and Cs 17

Figure 2.5 The configuration of differential current-mode SAR ADC. 20

Figure 2. 6 A simulation example of successive approximation binary search..... 21

Figure 2.7 The SAR logic of the current mode digital converter..... 22

Figure 2.8 The simulation results of the capacitance to digital conversion..... 24

Figure 2.9 INL and DNL of the current-mode SAR ADC..... 25

Figure 3.1 The architecture of the proposed SAR ADC..... 28

Figure 3.2 The timing blocks of SAR ADC conversion..... 30

Figure 3.3 The SAR logic circuit of conversion mode..... 30

Figure 3.4 The 3-bit example of proposed SAR ADC switching procedure. 32

Figure 3.5 The conventional level-shifter (a) and CMLS (b) 34

Figure 3.6 Top-plate sampling switch 35

Figure 3.7 The schematic of the designed comparator..... 36

Figure 3.8 Model of integrated capacitor along with parasitic capacitance 37

Figure 3.9 The equivalent circuit of the L-side capacitor array..... 38

Figure 3.10 The calibration operation step and Cv model..... 40
Figure 3.11 Example of the H-side upper 5 bits calibration procedure..... 42
Figure 3.12 Calibration switches control timing blocks of the main DAC and calibration DAC in calibration mode 45
Figure 3.13 SAR logic of calibration and timing of control signals 46
Figure 3.14 Layout of the proposed SAR ADC 48
Figure 3.15 The DNL and INL of SAR ADC (a) before (b) after calibration 49
Figure 3.16 The SAR ADC FFT spectrum (a) before (b) after calibration 49

LIST OF TABLES

Table 2.1: Comparisons with Previous Works 26

Table 3.1: The Calibration References' Resolution and ENOB After Calibration... 38

Table 3.2: Post-simulation results of the proposed SAR ADC after calibration..... 50

Table 3.3: Comparison of this work and other previous works 51

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