

Contents

1	Introduction	1
1.1	Ambulatory Health Care Systems	1
1.2	Body Area Networks	1
1.3	Scope of the Book	2
2	Introduction to Biopotential Acquisition	5
2.1	Introduction	5
2.2	Introduction to Biopotential Signals	5
2.3	Introduction to Biopotential Electrodes	6
2.3.1	Equivalent Circuit Model	7
2.3.2	Types of Biopotential Electrodes	8
2.4	Introduction to Biopotential Amplifiers	9
2.4.1	Interference Theory	10
2.4.2	Noise-Efficiency Factor (NEF) of Biopotential Amplifiers	11
2.4.3	State-of-the-Art in Instrumentation Amplifier Design	12
2.5	Introduction to Chopper Modulation Technique	13
2.5.1	Noise Analysis of Chopper Modulation Technique	14
2.5.2	Charge Injection and Residual Offset of Chopper Modulated Amplifiers	15
2.5.3	Signal Distortion in Chopper Modulated Amplifiers	17
2.5.4	CMRR of the Chopper Modulated Amplifiers	18
2.6	Conclusions	18
3	24-Channel EEG Readout Front-End ASIC	21
3.1	Introduction	21
3.2	ASIC Architecture	21
3.3	Current Balancing IA	22
3.3.1	Implementation	22
3.3.2	Measurement of Performance	24
3.4	CMRR Model for Biopotential Instrumentation Amplifiers	25
3.4.1	Systematic CMRR	26
3.4.2	CMRR Limit Due to Differential DC Electrode Offset	28
3.4.3	Verification of the CMRR Model	29
3.5	Programmable Gain Stage	30
3.5.1	Finite-Gain Compensated SC Amplifier	30
3.5.2	Programmable Gain Stage Implementation	32
3.6	Test Results	34
3.7	Conclusions	36

4	Biopotential Readout Front-End ASICs	39
4.1	Introduction	39
4.2	AC Coupled Chopper Modulated IA (ACCIA)	40
4.2.1	Architecture of the ACCIA	40
4.2.2	Architecture of the CBIA	44
4.2.3	Power-Noise Performance of the ACCIA	48
4.3	Chopping Spike Filter (CSF)	50
4.4	Low-Power Programmable Gain Stage	51
4.5	Single-Channel ExG Readout Front-End	53
4.5.1	Implementation	53
4.5.2	Measurement of Performance	56
4.5.3	Biological Test Results	61
4.6	Eight-Channel EEG Readout Front-End	63
4.6.1	Implementation	63
4.6.2	Measurement of Performance	68
4.6.3	Biological Test Results	71
4.7	Comparison with the State-of-the-Art	75
4.8	Conclusions	77
5	A Complete Biopotential Acquisition ASIC	79
5.1	Introduction	79
5.2	ASIC Architecture	79
5.3	Bias Generator Circuit	81
5.4	Class-AB Buffer Architecture	85
5.5	ACCIA with Coarse-Fine Servo-Loop	86
5.5.1	Structure of the ACCIA	86
5.5.2	Coarse Transconductance (CGM) Stage	90
5.5.3	Fine Transconductance (FGM) Stage	94
5.5.4	Integrator Stage	94
5.5.5	Current Balancing IA (CBIA) Architecture	95
5.5.6	Gain Stage	97
5.5.7	Implementation of the ACCIA	97
5.5.8	Fast Start-Up of the ACCIA	99
5.5.9	Power-Noise Performance of the ACCIA	100
5.5.10	Measurement of Performance	102
5.5.11	Comparison with State-of-the-Art	105
5.6	Chopping Spike Filter	106
5.7	Low-Power Programmable Gain Stage	107
5.8	Readout Front-End Channel Test Results	109
5.9	Square Wave Relaxation Oscillator	110
5.10	Analog-to-Digital Converter	113
5.10.1	Basic Operation Principle	113
5.10.2	Architecture	114
5.10.3	Capacitive DAC Implementation	117
5.10.4	Low-Offset Comparator Implementation	119

5.10.5 Test Results 123

5.11 Impedance Measurement and Calibration Modes 125

5.12 Biological Test Results 129

5.13 Summary of the Biopotential Acquisition ASIC 129

5.14 Conclusions 131

6 Wireless Biopotential Acquisition Systems 135

6.1 Introduction 135

6.2 A Wireless VEMP Acquisition System 136

6.3 A Wireless Two-Channel ExG Acquisition System 137

6.4 A 1 cm³ Wireless Eight-Channel EEG Acquisition System 141

6.5 Conclusions 145

7 Conclusions 147

7.1 Achievements 147

7.2 Suggestions for Future Work 149

Appendix 151

References 157

Index 163