

---

## Table of Contents

List of Figures .....	ix
List of Tables .....	xv
<b>1 WIRELESS SENSOR NETWORKS .....</b>	<b>1</b>
1.1 System Requirements .....	3
1.2 Energy Scavenging .....	4
1.3 RF Transceiver Requirements .....	5
1.3.1 Power Consumption .....	5
1.3.2 Datarate .....	5
1.3.3 Range .....	6
1.3.4 Sensitivity .....	6
1.3.5 Turn-On Time .....	7
1.3.6 Integration/Power Tradeoff .....	8
1.4 Contributions of this Book .....	9
<b>2 LOW POWER CMOS DESIGN FOR RADIO</b>	
<b>FREQUENCIES .....</b>	<b>13</b>
2.1 Weak Inversion RF CMOS .....	13
2.2 MEMS Background .....	15
2.3 Circuit Proof-of-Concept I: 300 $\mu$ W Pierce Oscillator .....	19
2.4 Circuit Proof-of-Concept II: Differential 300 $\mu$ W BAW-Based	
Oscillator .....	24
2.4.1 Analysis/Design .....	24
2.4.2 Experimental Results (1.9GHz) .....	28
2.4.3 Experimental Results (2.4GHz) .....	33
2.5 System Proof-of-Concept: Energy Scavenging Transmit Beacon	35
<b>3 TWO CHANNEL BAW-BASED TRANSCEIVER .....</b>	<b>41</b>
3.1 Architecture .....	41
3.2 LNA Design .....	42

3.3	CSA Analysis and Design .....	44
3.3.1	Active Inductor .....	44
3.3.2	Standalone RF Amplifier .....	47
3.3.3	In-Situ RF Amplifier .....	51
3.4	RF Detector Analysis and Design .....	53
3.5	Transmitter Architecture and Design .....	55
3.6	Experimental Results .....	55
3.6.1	Implementation .....	55
3.6.2	Receiver .....	56
3.6.3	Transmitter .....	57
3.7	Conclusions .....	59
<b>4</b>	<b>SUPER-REGENERATIVE RECEIVER DESIGN .....</b>	<b>61</b>
4.1	History of the Super-Regenerative Receiver .....	61
4.2	Motivation .....	62
4.3	Architecture .....	65
4.4	Analysis .....	66
4.4.1	Operation .....	66
4.4.2	Super-Regenerative Gain .....	66
4.4.3	Super-Regenerative Bandwidth .....	68
4.4.4	Quench Frequency Limitations .....	71
4.5	LNA/Oscillator Design .....	72
4.6	Additional Circuitry .....	74
4.7	Experimental Results .....	74
4.7.1	Board Design .....	74
4.7.2	Testing Methodology .....	74
4.7.3	Results .....	75
4.8	Discussion .....	78
<b>5</b>	<b>FULLY INTEGRATED SUPER-REGENERATIVE TRANSCIEIVER .....</b>	<b>81</b>
5.1	Architecture .....	81
5.2	RF Front-End Circuit Design .....	81
5.3	Pulse Width Demodulator .....	83
5.3.1	Filter Specifications .....	83
5.3.2	Filter Synthesis and Design .....	85
5.4	Capacitance Tuning .....	88
5.5	Chip Implementation .....	89
5.6	Measured Results .....	90
5.6.1	Serial Interface .....	90
5.6.2	RF Front-End .....	91
5.6.3	Temperature Compensation .....	96
5.6.4	Baseband .....	98
5.6.5	Link Demonstration .....	99
5.7	Discussion .....	99

<b>6</b>	<b>INTEGRATION TECHNIQUES</b>	103
6.1	Silicon Reference Clocks	103
6.1.1	Silicon Resonator Background	104
6.1.2	Circuit Analysis and Design	106
6.2	Flip-Chip Packaging	112
6.2.1	Oscillator Flip-Chip	113
6.2.2	Super-Regenerative Flip-Chip	114
6.3	Conclusions	116
<b>7</b>	<b>ULTRA-LOW POWER RADIO IN A PACKAGE USING ULTRA-WIDE BAND TECHNOLOGY</b>	117
7.1	Introduction	117
7.2	UWB for Sensor Networks	118
7.2.1	Air Interface Definition	118
7.2.2	UWB System Implementation	120
7.3	UWB Radio Design	122
7.3.1	UWB Pulse Generator Design	123
7.3.2	UWB Receiver Design	129
7.4	Heterogeneous Integration	134
7.4.1	Introduction	134
7.4.2	Layered Design Approach	135
7.4.3	Elementary Application	140
<b>8</b>	<b>LOW ENERGY WIRELESS COMMUNICATION</b>	143
8.1	Introduction	143
8.2	Fundamental Energy Requirements of Wireless Communication	143
8.2.1	Theoretical System Energy Limits	146
8.3	Low Energy Transceiver Design	149
8.3.1	Modulation Scheme	149
8.3.2	Minimizing Overhead Power	153
8.3.3	Receiver Noise Factor and Passive Voltage Gain	157
8.3.4	Efficient PAs with Low Power Output	162
8.4	A Low Energy 2.4GHz Transceiver	165
8.5	Summary and Conclusions	166
<b>9</b>	<b>CONCLUSIONS</b>	171
	<b>References</b>	175
	<b>Index</b>	181





<http://www.springer.com/978-0-387-30930-9>

Ultra-Low Power Wireless Technologies for Sensor  
Networks

Otis, B.; Rabaey, J.

2007, XV, 184 p., Hardcover

ISBN: 978-0-387-30930-9