Preface

Wireless Body Area Networks (WBANs) are expected to promote new applications for the ambulatory health monitoring of chronic patients and the elderly population, aiming to improve their quality of life and independence. These networks are composed by wireless sensor nodes that measure physiological variables and transmit it, for example, to the patients' smartphone, which may acts as a gateway to a remote medical assistance service. A key element of such sensor nodes is the wireless transceiver as it often dominates the overall power budget. Therefore, to provide a high degree of energy autonomy, wireless transceivers with an ultra low power consumption are needed. In this book, a transceiver architecture and implementation is presented, which targets such highly power constrained applications and employs the Bluetooth low energy standard.

At the architectural level, four main strategies are identified to obtain an ultra low power consumption. First, a direct-conversion receiver architecture is selected as it relaxes the requirements for the local oscillator and allows for a low power baseband section. Secondly, the number of active radio-frequency (RF) blocks has to be minimized in order to end up with as few RF nodes as possible that have to be driven by power-hungry circuits. Third, the remaining RF nodes have to be implemented with a high impedance level, which leads to a low required transconductance in the driving blocks and so reduces the power consumption. Finally, a low complexity demodulation scheme avoiding quadrature multi-bit analog-to-digital converters (ADCs) is needed.

The resulting transceiver architecture employs a passive receiver frontend architecture and a transformer at the antenna interface to boost the internal RF impedance. The carrier frequency is generated by a quadrature voltage controlled oscillator (QVCO), which is directly modulated to also synthesize the required signaling for transmission. In the baseband, the proposed transceiver employs a phase-domain ADC (Ph-ADC) which needs only 4 bits of resolution to demodulate the received signal.

In order to further improve the energy autonomy of the wireless sensor node, the possibilities for including an RF energy harvester with the presented transceiver frontend are studied. A fundamental problem that has to be resolved is the decoupling of the harvester from the transceiver while using the same antenna. In the proposed architecture the harvester is decoupled with an RF-switch that can be turned on passively, i.e., by utilizing the incoming RF power only. This approach stands out due to its low degradation of the transceiver performance as well as its small area occupation and hence low implementation cost.

On circuit level, the main contributions of this book are (a) a passive cancelation network to reduce the magnetic coupling-induced quadrature error of the QVCO, (b) a simple 4-transistor cell to directly modulate the QVCO tank capacitance in aFsteps, which has been verified to be sufficiently stable within the industrial temperature range, (c) a new current-domain linear combiner to provide the phase generated signals for the 4-bit Ph-ADC, which allows for a both area- and power-efficient implementation, and (d) an RF-switch that can be turned on without an external power supply using a start-up rectifier.

The proposed transceiver is implemented in a 130 nm CMOS technology using four integration steps which progressively complete the transceiver with the harvester. In the receive mode, the measured power consumption of 1.1 mW advances the state of the art as it is the lowest reported for a narrowband transceiver in the 2.4 GHz ISM band, which fulfills one of the typical WBAN standards. With a sensitivity of −81.4 dBm the receiver also achieves a competitive performance providing a sufficient link budget for a short-range data link. Concerning the performance in transmit mode, the power consumption of 5.9 mW and 2.9 mW in normal and back-off mode, respectively, is among the lowest reported so far for narrowband transmitters. However, the total transmitter efficiency of up to 24.5 % is significantly higher compared to other implementations due to the increased internal RF impedance. The harvester achieves a decent peak efficiency of 15.9 % and is able to progressively charge up an energy storage device for pulsed input signals emitted by an active WLAN router, for an expected distance of up to approximately 30 cm. Measurements also verify that the degradation of the transceiver, which arises from sharing the same antenna interface with the harvester, is less than 0.5 dB.

In conclusion, an ultra low power transceiver architecture for WBAN applications is presented which advances the state of the art in various aspects, as verified experimentally. Also the compatibility of the proposed architecture with energy harvesting techniques is shown, providing a possibility to improve the energy autonomy of wireless sensor nodes.

This book is organized as follows. After an introductory Chap. 1, Chap. 2 reviews the state-of-the-art of wireless low power transceivers. Then, Chap. 3 presents the four main strategies to reduce the power consumption and Chap. 4 describes the proposed transceiver in detail. Chapter 5 shows the co-integration of the energy harvester and finally Chap. 6 concludes this thesis.

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