Ain Shams University
Faculty of Engineering
Electronics and Communications Engineering Department

Design of Low-Power Circuit Building Blocks for UWB Transceiver

A THESIS

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By

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BIOGRAPHY

Michael Youssef was born on November ١٩, ١٩٧٩ in Cairo, Egypt. He completed his high school at Collège de la Salle, Cairo in July ١٩٩٦. He graduated from Ain Shams University, Cairo in July ٢٠٠١ with a B.Sc. degree in Electronics and Communications Engineering. He works as a teaching and research assistant at the ECE department, Ain Shams University from September ٢٠٠١ to present. His interests are in RFIC / MMIC design for wireless and optical communication systems.

STATEMENT

This dissertation is submitted to Ain Shams University in partial fulfillment of the requirements for the degree of Master of Science in Electrical Engineering (Electronics and Communications Engineering).

The work included in the thesis was carried out by the author at the Electronics and Communications Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis has been submitted for a degree or a qualification at any other university or institute.

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ABSTRACT

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Whilst most wireless communication systems seek to increase capacity by increasing signal to noise ratio over a narrow frequency band, Ultra-Wide Band (UWB) systems increase capacity by utilizing a very large bandwidth. This means that the transmitted signals have a very wide spectrum, hence the term 'ultra-wideband'. By spreading the transmission over a very wide frequency range, it is possible for an UWB system to operate beneath the noise floor of most systems. These properties of very low power and very wide bandwidth have many advantages, including increased security, high speed transmission, and high processing gain with minimal interference to other spectrum users.

In this thesis, the various possible transceiver architectures for the ٣.١-١٠.٦ GHz UWB communication systems are investigated. The complete front-end of an impulse-based UWB radio is described in a detailed analysis and the key components of the system are designed with Austriamicrosystems (AMS) Silicon Germanium ٠.٣٥ μm process. The three important front-end functions highlighted in this work are: UWB signal generation, low-noise amplification, and correlation-based detection of the received pulse stream.

The implementation of Low-Noise Amplifiers (LNAs) is one of the challenging aspects in emerging UWB systems. The role of LNAs for wireless applications is examined in detail. LNA performance parameters are explained illustrating their impact on the system performance. Different UWB LNA implementations in CMOS and SiGe HBT BiCMOS technologies are presented and compared. Outperforming the other topologies, the UWB inductively-degenerated cascode topology is chosen for the implementation of the LNA. Optimization techniques of the LNA's noise figure, linearity, and bandwidth are utilized in the design. The simulated LNA performance parameters are: ٢-١١ GHz ٣-dB-bandwidth, ٣ dB average noise figure, ١٢ dB forward gain, -١٢.٥ dBm $P_{١\text{-}dB}$, -٣.٥ dBm IIP٣, -١٠ dB input return loss, and ٦٠ dB reverse isolation. The LNA consumes ١٤ mW from a ٢.٧ V supply.

Ultra-Wideband active mixer is a key component of the analog correlator subsystem in the impulse-based UWB receiver. An analysis of the main bandwidth limitations in active mixers based on the Gilbert Cell mixer topology is performed. Advanced circuit techniques for wideband operation with high degree of gain flatness and phase linearity are exploited. Simulation results for the designed mixer implemented in ۰.۳۵ μm SiGe HBT process show ۱۱ dB conversion gain with ۳-dB bandwidth of ۲۲ GHz and ۹ GHz at the input and output ports respectively. The double-sideband noise figure (DSB-NF) is less than ۸ dB. The designed mixer demonstrates good linearity: -۷ dBm $P_{۱\text{-dB}}$ and -۱.۵ dBm IIP۳. It consumes ۲۰ mW from a ۳.۳ V supply.

Gaussian derivative monocycle waveforms are the most appropriate for UWB impulse radio. Different methods for generating Gaussian and Gaussian derivative pulses have been used in impulse radar systems. However, most of these methods are not compatible with IC technology due to their high power nature. A basically simple and IC-compatible technique has been devised for the implementation of the pulse generator. This technique uses the fact that a Gaussian waveform can be approximated to a weighted sum of tanh waveforms, therefore allowing the use of the basic BJT differential pair for the implementation. Simulation results show compliance of the generated UWB pulses with the regulations and appropriateness of the template pulses for impulse-based receivers.

Key Words: UWB, RFIC, MMIC, Transceiver, LNA, Mixer, Pulser, SiGe, Wireless Applications

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This Work is dedicated to my GOD.

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