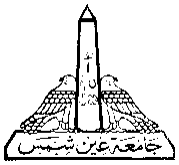

AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electronics Engineering and Electrical Communications

Ultra-Low Power Transceiver for no-battery Applications

A Thesis submitted in partial fulfillment of the requirements of the degree of

Master of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

by

Amr Mohamed Abdel Aziz Abuellil

Bachelor of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

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Cairo - (2016)

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Degree: **Master of Science in Electrical Engineering**

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Statement

This thesis is submitted as a partial fulfillment of Master of Science in Electrical Engineering Engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Amr Mohamed Abdel Aziz Abuellil

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Date: 5 January 2016

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Acknowledgement

I wish to thank Dr. Ahmed Eladawy for his guidance and support in this research project. A special thanks is due to Prof. Mohamed Dessouky for his sincere advice through the project and publications and through the thesis writing. Though not participating in this project I cannot miss showing all gratitude to Prof. Wael Fikry for his support in every step of my career since the graduation project and teaching me the basics for research and self-confidence.

I would like to thank all working in Silicon Vision for supporting this work by providing tools required to finish this project, special thanks to Mohamed Tawfik, Fady Atef, Ahmed Ibrahim, Eslam Saad and Amr El-Hossieny. This project tape-out truly wouldn't have reached the light without your help and advises in layout which I didn't know anything about it at the start of the project nor the digital design, I can`t tell you how blessed I am to have you as my friends.

My Wife Basma Serry, Very special thanks to you for all the time and effort you spent with me to organize and proof-read this work, you were truly a helpful partner in times of need, I would also like to thank you for constant encouragement and confidence in my abilities. Above all, thank you god for providing me the strength to complete this work.

Amr Abuellil

January 2016

Abstract

Amr Mohamed Abdel Aziz Abuellil "Ultra-low power transceiver for no- battery applications", Master of Science dissertation, Ain Shams University, 2016

This thesis is an attempt to design a low power RF transceiver in the 902-928MHz Industrial/Scientific/Medical (ISM) band, starting from high level application needs down to network layer considerations and ending up with the physical layer prerequisites to achieve such demands for upper layers. The main motive behind this work is minimizing power consumption to tens of micro watts instead of tens of milli-watts, enabling a wireless node to work independent of conventional power sources(batteries) and rely on energy harvesting techniques thus removing the periodic maintenance (e.g. battery replacement) in Wireless Sensor Networks (WSN).

The ability to comply with traditional wireless communication standard`s (e.g. Blue-tooth, WiFi) specifications is difficult under ultra-low power budget, that's why new tailored standards emerged for these considerations (e.g. IEEE 802.15.4). Some of these networks operate at custom proprietary standard specification and networking protocols. In addition, achieving this power budget on the physical layer requires not only block level optimization, but rather a complete architecture make over; for example replacing the Phase locked loop (PLL) with digitally calibrated oscillators to meet the required frequency accuracy for transmission thus skipping the use of power hungry LC oscillators and frequency dividers. To maintain frequency stability without the use of PLLs, a new method for accurate frequency calibration is implemented here using a digital calibration algorithm combined with digital to analog converter (DAC) to control the ring oscillator (RO) frequency prior transmission.

The work presented here is a joint project with Texas A&M University which made it possible to fabricate the transceiver on 180nm IBM technology, manufacture a testing board and perform full characterization in their labs. We succeeded in achieving transmission energy figure of 0.2nJ/bit @ -15dBm output power and a data rate of 3Mbps.

This also gave a deeper insight on the practical issues faced in such designs providing opportunities for further investigation and future improvements.

Keywords: *low-power radio, wireless sensor networks (WSN), energy harvesting, RF communication, ring oscillators, digital calibration, PLL-less design.*

Summary

Faculty of Engineering – Ain Shams University

Electronics and Communication Engineering Department

Thesis title: **"Ultra-low power transceiver for no- battery applications"**

Submitted by: **Amr Mohamed Abdel Aziz Abuellil**

Degree: **Master of Science in Electrical Engineering**

Thesis Summary:

Wireless Sensor networks is seeking continuous reduction in power consumption, since frequent battery change is impractical. This transceiver aims to utilize multiple phases from oscillator to generate higher frequency component at transmitter and receiver side, enabling oscillator design at much lower frequency than carrier frequency with a sub mW consumption. This enables installation of this transceiver on energy harvesting system without using any conventional power source.

The thesis is divided into six chapters, in addition to lists of contents, tables, equations and figures. As well as list of references, symbols, abbreviations and three appendices.

Chapter 1

It includes thesis introduction and explains the growth trends of wireless connected devices numbers, as well as the necessity in power reductions on multiple levels especially the physical radio level. This chapter is concluded with the thesis outline.

Chapter 2

It provides an overview on Wireless Sensor Networks (WSN) applications, briefly discussing the network layer, providing elaborate description of the physical layer with

emphasis on energy aware implementations for these layers. This chapter ends with presenting features required for low power radios.

Chapter 3

It presents a survey on low power design techniques for transceivers in literature, explaining which low power strategy this thesis will adopt.

Chapter 4

This chapter describes the design of each block in the transceiver, from system to transistor level followed by simulation results.

Chapter 5

This chapter contains layout, die photo and measurements results. An overall performance summary will conclude this chapter.

Chapter 6

The thesis ends by giving a conclusion, highlighting various design recommendations and findings witnessed in the design of low power transceivers, followed by a list of suggested future work circuits for a complete solution integration.

Supervisors:

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