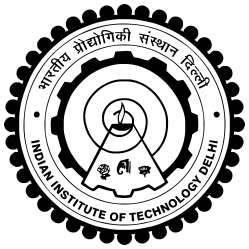
CHARGE CONTROLLED OSCILLATORS AND THEIR APPLICATION IN FREQUENCY SYNTHESIZERS

ROOHIE KAUSHIK



Department of Electrical Engineering
Indian Institute of Technology Delhi
March 2017

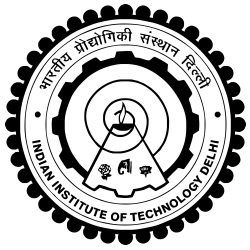
CHARGE CONTROLLED OSCILLATORS AND THEIR APPLICATION IN FREQUENCY SYNTHESIZERS

by

ROOHIE KAUSHIK

Department of Electrical Engineering

Submitted
in fulfillment of the requirements of the degree of Doctor of Philosophy
to the



Indian Institute of Technology Delhi

March, 2017

To my loving *MOTHER* –

My foundation, strength and motivation

This thesis is a gift to her.

Certificate

This is to certify that the thesis entitled **"Charge Controlled Oscillators and their Application in Frequency Synthesizers"**, being submitted by **Miss. Roohie Kaushik** for the award of the degree of **Doctor of Philosophy** to the Department of Electrical Engineering, Indian Institute of Technology Delhi, is a record of bonafide work done by her under our supervision and guidance. The matter embodied in this thesis has not been submitted to any other University or Institute for the award of any other degree or diploma.

Shouri Chatterjee
Associate Professor,
Department of Electrical Engineering,
Indian Institute of Technology Delhi,
Hauz Khas, New Delhi - 110016,
INDIA.

G. S. Visweswaran
Professor,
Department of Electrical Engineering,
Indian Institute of Technology Delhi,
Hauz Khas, New Delhi - 110016,
INDIA.

Acknowledgements

I would like to express my greatest gratitude to my supervisors Professor Shouri Chatterjee and Professor G.S.Visweswaran for their guidance, interest, advice, support, for their understanding of the subject and help throughout the course of present work. I am indebted to them for introducing me to the area of RF-circuit design. I am very grateful for having the oppurtunity to work with them and hope that I shall continue to have their blessings in the future.

I would also like to thank Professor B.Bhaumik for helping and motivating me throughout the course of this work. She was always concerned about my progress and whenever I went to her she was very kind to extend me the helping hand.

My special thanks to Professor Suneet Tuli, Professor B.Bhaumik and Professor Jayadeva members of my "Student research committee" for all the constructive ideas and criticism throughout my research work.

The batches of M. Tech students who came and went through our group were really the people who made my stay at IIT enjoyable. I thank all of them for the treats, nightouts and all the fun we had together. My PhD seniors, Anoop C Nair, Girish, Sultan, who helped me as an ideal senoir in every difficult step of my research. Anoop C Nair, who has always been there for all my technical discussions and giving a sincere piece of advice every moment. Navdeep Kaur Dhaliwal and Akanksha Jain being the best roommates ever. I have never faced a single bitter moment with them. Dheeraj Mehra, who was always there as a friend and we together learned many lessons of life. I remember with great pleasure the time I

spent with my colleagues at IIT Delhi. It was great fun to work together in a close and fruitful collaboration with Kinde Anlay, Dhanaraj K.J, Gajendranath Choudhary, Sanjeev Jain, Sanjeev Kumar, Nagarjuna Nallam, Bhuvan, Ritabrata and Srujana formed. Kinde Anlay, has never made me feel alone. I am thankful to Gajendranath Choudhary, who introduced me to Sandhya Gajendranath. She is like my sister, my visits to her house gave me a homely feel. All the fun I had with Atul, Supriya, Rohit, Deeksha, Sweta, Amandeep, Deepak, Arti has kept me happy in my last year.

I am grateful to the Department of Electrical Engineering at the Indian Institute of Technology Delhi for providing me the excellent work environment during the past years. I would specially like to mention the help which Mr. Rakesh Kumar and Mr. Jiley Singh have provided me during my research work. I thank Ravi Solders for helping me with their expertise on PCB for making my test boards.

I would like to thank my grandparents, parents, aunty, uncles, sisters and brothers for their individual support throughout my course. I could not have finished this work without their love and support. The emotional support extended by them all through this journey can never be thanked in words. They are and will remain as my motivation for success.

Finally, I acknowledge all other who have helped me and whose names could not be accommodated in this brief acknowledment.

ROOHIE KAUSHIK

Abstract

Tunable LC-oscillators, have been extensively used in RF communication systems. It can be used as a local oscillator for a mixer, or for generation of signals with frequencies in multiples of reference signals. Conventional tunable LC-oscillators are either voltage-controlled oscillators (VCOs) or digitally-controlled oscillators (DCOs). VCOs are tuned by changing the capacitance of a varactor in an LC-tank. DCOs are digitally tuned by switching on/off capacitors in an LC-tank.

In this dissertation we introduce a novel idea of frequency of oscillation as a function of charge. This new category of LC-oscillators is termed as charge-controlled oscillators. A charge-controlled oscillator consists of a Gaussian surface around the inductor of the LC-tank. The charge held inside this Gaussian surface remains conserved (or constant), which decides the frequency of oscillation. The charge remains constant unless it is disturbed by some external source or it has a path to leak. Four different configurations of charge-controlled oscillators are explored in this thesis. The designs were implemented in a 0.13 μm CMOS process. Two such charge-controlled oscillators were fabricated and the figure-of-merits of the fabricated charge-controlled oscillators are 179 dB and 163.4 dB, oscillating at 3.5 GHz and 3 GHz respectively.

In this thesis we also introduce frequency synthesizers built around a charge-controlled oscillators. The use of charge-controlled oscillators removes the need of an explicit loop-filter. The desired loop-filter transfer function can be designed into the charge-pump and charge-controlled oscillator. The analysis of such frequency synthesizers with examples

is also discussed. Further, an all-digital phase locked loop (ADPLL) based on a charge-controlled oscillator is also demonstrated. ADPLLs designed with charge-controlled oscillators are significantly simpler than the conventional ADPLLs.

Quadrature charge-controlled oscillators have also been described. Conventionally quadrature outputs were generated by coupling two identical VCOs. We show here that conventional way of generating quadrature phase fails in case of charge-controlled oscillators. The quadrature phases can be generated by using a single LC-tank with distributed inductance and capacitance in a charge-controlled oscillator.

Table of Contents

List of Figures

List of Tables