Ain Shams University

Faculty of Engineering

Electronics and Communications Department

Design of Switched Capacitor DC-DC Converters

A Thesis

Submitted in partial fulfillment of the requirements of a Master of Science degree in Electrical Engineering

Submitted by:

Ahmed Ibrahim Saeed

B.Sc. of Electrical Engineering

(Electronics and Communications Department)

Ain Shams University, 2011

Supervised by:

Prof. Dr. Hani Fikry Ragai

Dr. Sameh Assem Ibrahim

Cairo, 2017

Ain Shams University

Faculty of Engineering

Electronics and Communications Department

Examiners' Committee

Name: Ahmed Ibrahim Saeed

Thesis: Design of Switched Capacitor DC-DC Converters

Degree: Masters of Science in Electrical Engineering

Title, Name and Affiliation	**Signature**
Prof. Dr. Mohamed Rizk Mohamed Rizk Alexandria University, Faculty of Engineering, Electronics & Communications Dept.	. . . . .
Prof. Dr. Mohamed Amin Dessouky Ain Shams University, Faculty of Engineering, Electronics & Communications Dept.	. . . . .
Dr. Sameh Assem Ibrahim Ain Shams University, Faculty of Engineering, Electronics & Communications Dept.	. . . . .

Curriculum Vitae

Name: Ahmed Ibrahim Saeed

Date of Birth: 07/12/1988

Place of Birth: Cairo, Egypt

First University Degree: B.Sc. in Electrical Engineering

Name of University: Ain Shams University

Date of Degree: June 2011

Statement

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

The work included in this 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 was submitted for a degree or a qualification at any other university or institution.

Name: Ahmed Ibrahim Saeed

Date: 27/11/2017

Acknowledgment

All praise is due to ALLAH, Most Merciful, who taught man what he did not know. I would like to thank ALLAH Almighty for bestowing upon me the chance, strength and ability to complete this work.

I would like to express my gratitude to my supervisor, Dr. Sameh Ibrahim, for his guidance, continuous encouragement and fruitful discussions. I would also like to thank my professor, Prof. Hani Ragai, for his academic guidance throughout my career in the field of integrated circuits .

Special thanks to Prof. Alaa Hassan and Mohamed Sakr for their help in the mathematical formulation for the optimization problem of the thesis.

I would like also to thank my colleagues at Si-Ware Systems for their support and useful thoughts. Special thanks to Amr Essam , who guide me through my first charge pump design. I would like to thank Botros George for his insightful thoughts.

Last but not least, I would like to express my gratitude to my parents for their continuous support,motivation and unconditional love.

Ahmed Ibrahim Saeed

Electrical and Communications Department (ECE)

Faculty of Engineering

Ain Shams University

Cairo, Egypt

November 2017.

Abstract

Faculty of Engineering - Ain Shams University
Electronics and Communication Engineering Department

Thesis title: **Design of Switched Capacitor DC-DC Converters**
Researcher Name: **Ahmed Ibrahim Saeed**
Degree: **Masters of Science in Electrical Engineering**

Abstract

A novel sizing methodology for Dickson charge pumps with pure capacitive loads is presented. The methodology is based on dynamic analysis to minimize the rise time of the charge pump up to 25% under a given circuit area without power or area overhead and paves the way for a comprehensive rise-time minimization using the optimum number of stages. The methodology allows the designer to choose the pumping capacitor of each stage and thus efficiently utilize the circuit area which is mostly dominated by the pumping capacitors area.

The methodology is validated through the implementation of a six-stage charge pump-based driver in 180-nm standard low-voltage CMOS technology. The driver is used for the excitation of ultrasonic transducers with 34 V at a resonance frequency of 220 KHz. A rise time of only 512 nS

is achieved. The driver consumes 10.6 mA drawn from a 5-V supply at a pumping frequency of 50 MHz and occupies an area of 0.2 mm^2.

key words: design methodology, switched-capacitor DC-DC converters, charge pump, rise time.

Summary

Faculty of Engineering Ain Shams University

Electronics and Communication Engineering Department

Thesis title: **Design of Switched Capacitor DC-DC Converters**

Researcher Name: **Ahmed Ibrahim Saeed**

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

Summary

The thesis is divided into five chapters as listed below:

Chapter 1

Chapter 1 introduces the motivation and objectives of this work. At the end of this chapter, the thesis organization is described.

Chapter 2

Chapter 2 is an overview on charge pump circuits, where the theory of operation, specifications, different topologies and sub-blocks of charge pumps are presented. Also, a survey on the state-of-the-art design methodologies for charge pumps is discussed.

Chapter 3

Chapter 3 introduces a novel sizing methodology for the pumping capacitors of the charge pump to minimize the rise time of charge pumps with capacitive loads. The methodology is based on dynamic analysis of N-stage Dickson charge pump with unequal pumping capacitors, followed by finding the optimal pumping capacitor values. Afterwards, the improvement in the rise time in case of using unequal pumping capacitors when compared with the case of equal pumping capacitors is evaluated..

Chapter 4

Chapter 4 validates the methodology through SPICE simulations. The methodology is validated through the implementation of a six-stage charge pump-based driver in standard low-voltage CMOS technology. The layout for the driver is made and post layout simulations are performed to account for parasitics. Finally, a performance comparison between the HV driver using the proposed methodology and other published HV drivers is summarized.

Chapter 5

Chapter 5 concludes the thesis. The suggested future work is outlined as well.

Supervisors

- Prof. Hani Fikry Ragai
- Dr. Sameh Assem Ibrahim

Contents