

The First-Ex

Charge Pumps for Today's Low-Cost, High-Performance Mobile Devices

A groundbreaking tool for circuit design engineers, **Charge Pump Circuit Design** is the first book to focus solely on the design and implementation of charge pumps used in EEPROMs, Flash memory, White LED drivers, and a myriad of other circuits finding mass applications in PDAs, digital cameras, MP3 players, video recorders, cell phones, USB drives, and more.

Written by two of today's leading circuit designers, **Charge Pump Circuit Design** explores the basic operations, design criteria, and newest approaches for designing state-of-the-art charge pumps. The authors explain the different architectures and requirements, providing comprehensive information for each stage in the design process. Filled with 100 detailed illustrations, this time-saving reference also presents a wealth of practical design tips and potential pitfalls to avoid.

Charge Pump Circuit Design features:

- The latest design techniques for creating highly efficient charge pumps for any type of application requirement
- Step-by-step guidelines for completing a charge pump design—from initial concept to implementation of actual layout
- Thorough mathematical derivations and analyses of operations that are applicable to all charge pump requirements, regardless of the system being designed

Inside This Landmark Design Reference:

- History of High-Voltage Charge Pumps
- Basic Operations of Charge Pumps
- Criteria of a Generic Charge Pump
- How to Design a Basic Charge Pump
- How to Design a Better Charge Pump
- Charge Pump Architectures
- Future Design Reference

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Charge Pump Circuit Design

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Samaddar

Charge Pump Circuit Design

✓ Architecture

✓ Concept to Implementation

✓ Operation and Analysis

Charge Pump Circuit Design

Feng Pan
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Preface

Charge pumps are finding increased attention and novel diversified usage in the new era of nanometer-generation chips used in different systems, specifically those incorporating nonvolatile memory. Many of the present and future nanometer-generation chips' performance depend heavily on the ability to efficiently generate high voltages on-chip while meeting stringent power and area requirements. And yet, charge pump design, being purely analog in nature and involving high voltage, needs meticulous design techniques, intensive semiconductor device analysis, careful design layout planning, and accurate parasitic extraction process to produce excellent results in real implementation on silicon.

This book is a product of our years of quest for a practical book on charge pump circuit design. Having made significant contributions in different successful projects at various companies, we have always felt the need for a book on the topic of charge pump design. From our early days we constantly felt the challenge of working on a subject where there are no books and our sources of information were limited to only a few pages of description on various text books and different IEEE-published papers and journals. Most of these documents, while giving us skeletal ideas about the basic architecture and enhancements of charge pumps, did nothing to guide us intricately through different design conceptions and implementation processes. Charge pump, being a pure analog design, carries an inherent risk of unanticipated effects, which when overlooked can significantly reduce circuit performance or cripple the circuit operation.

Both of us have individually looked for books or materials on this topic and asked colleagues and veterans for any published materials, but we soon found out that everyone wished there was a book on this particular topic. By writing this book we have tried to bring our combined personal design experiences along with the knowledge assimilated from our study of different journals and research papers. This book covers the basics of charge pump circuits in detail and provides a thorough mathematical derivation and analysis of charge pump operation. It also strives

to explain the different aspects for an excellent charge pump design, and explains each step in detail. Every effort has been made to provide enough hands-on design information, potential pitfalls to avoid, and practical ideas harnessed from our years of designing charge pumps, which are being used in many chips, finding mass scale adoption.

This book assumes a basic knowledge of semiconductor device physics and MOSFET operation and is targeted toward almost every semiconductor chip design engineer who is involved in analog circuit design and memory circuit design. The book takes a relatively novice reader through various aspects and gives sufficient information to enable him or her to complete their design from conception to actual layout implementation. Further audiences include systems designers and board level integrators. Also this book should be essentially helpful to almost all electrical engineering professors and students at all levels.

This book is organized into nine chapters. Chapter 1 starts with a history of charge pump evolution from the Noble award winning work of Cockcroft and Walton to the eventual adaptation of John F. Dickson. Chapter 2 is intended for a quick refresh of basic MOS device physics and different second order effects relevant to charge pump operation. It also discusses SPICE simulators and BSIM models while providing suggestions to avoid the dreaded SPICE convergence issue. Chapter 3 dives straight into the heart of charge pump operation and quantitatively analyzes the pump characteristics. Chapter 4 is where the basic implementation details are discussed along with different charge pump controlling blocks. It analyzes the different pump regulation schemes and quantifies them. Chapter 5, a prelude to Chapter 9, introduces the different parameters for charge pump specifications and discusses various implementation details. Now, once the basic operation of a 2-phase charge pump and its many characteristics and specifications have been understood, Chapter 6 takes it to the next level and discusses how to design a better charge pump. Chapter 7 discusses various charge pump architectures, such as the modified 2-phase charge pump, the 4-phase charge pump, and the CTS charge pump. Chapter 8 provides future design references and discusses different circuit and system effects that affect the performance of the pump. Finally, Chapter 9 provides a practical design example and discusses the influence of different parameters while analyzing the characteristics of a charge pump.

It is believed that if the reader applies appropriate techniques, which have been presented here, he or she should be able to design charge pumps that meet design and performance specifications and produce excellent operating circuits on silicon.

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Many thanks to those who supported me in the past to make this book production possible.

Feng Pan

Writing this book began with a lot of energy and excitement. However, after about six months of persistent writing, drawing, and revising, while meeting tough deadlines, schedules, and surprises at the office, we reached midway in the book and immediately began to feel the streaks of insanity, realizing that the book will never finish on time. It was only through the continued efforts, support, and help of many outstanding individuals that we were able to complete this book.