Design and Analysis of Fibonacci Charge Pump

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Abstract

This paper addresses the enhancement of efficiency in the **Fibonacci charge pump (FCP)**, a switched-capacitor voltage multiplier designed for low-power, high-voltage generation. The main focus is on identifying and mitigating power loss mechanisms inherent in the original FCP design, including diode voltage drops and shoot-through currents in auxiliary inverter MOSFETs. To reduce these losses, the study proposes the use of low forward-voltage Schottky diodes (PMEG2010AEB) and a gate voltage regulation technique employing capacitive dividers to limit transistor channel conductivity, thus decreasing switching currents. Simulation and experimental results demonstrate that these strategies yield a streamlined FCP with efficiency greater than 70% over a wide output current range (approximately 1.5 mA to 10 mA) at an input of 3 V and output voltages exceeding 30 V. The improved design exhibits a flatter efficiency curve and lower equivalent series resistance compared to the original structure, making it a viable solution for efficient, compact voltage boosting in integrated and discrete applications.

Keywords: Fibonacci Charge Pump, MOSFET, Schottky Diodes.

I. INTRODUCTION

The **Fibonacci charge pump (FCP)** is a switched-capacitor voltage multiplier architecture designed to achieve higher voltage gains per stage compared to conventional charge pumps such as the Dickson charge pump. Each stage of the FCP provides a voltage gain defined by Fibonacci numbers (1, 1, 2, 3, 5, 8, etc.), enabling efficient voltage multiplication with fewer stages. The single-stage FCP, as implemented in the original design, employs passive Schottky diode switches and active MOSFET switches arranged to transfer charge sequentially through capacitors synchronized by clock signals. This arrangement allows for voltage boosting from a low input (e.g., 3 V) to a significantly higher output voltage in a compact, low-power form. Although the FCP is more sensitive to parasitic capacitances and switching delays than Dickson charge pumps, the single-stage replication provides a foundational understanding of the charge transfer mechanism and voltage gain principles inherent to the Fibonacci approach.

II. PURPOSE OF FIBONACCI CHARGE PUMP

The purpose of the Fibonacci charge pump is to provide an efficient voltage multiplication method based on a switched-capacitor architecture. Specifically:

Higher Voltage Gain: Each stage's voltage gain corresponds to a Fibonacci number, enabling higher output voltages with fewer stages compared to traditional charge pumps.

Compact Design: The FCP uses capacitors and switches to transfer charge, making it suitable for low-power and space-constrained applications

Energy Efficiency: By optimizing stage gains and switching techniques, the FCP reduces power losses and improves overall efficiency.

III. WORKING PRINCIPLE

The Fibonacci charge pump operates by sequentially charging and transferring charge through capacitors arranged in stages according to Fibonacci numbers. Each stage consists of capacitors, diodes, and MOSFET switches controlled by complementary clock signals. During one half of the clock cycle, certain capacitors are charged in parallel from the input voltage through diodes. In the other half, these capacitors are connected in series, transferring their stored charge to the next stage, effectively increasing the voltage. The voltage gain of each stage corresponds to a Fibonacci number, producing an overall voltage multiplication that grows faster than traditional charge pumps. This process continues through all stages, boosting the output voltage to a higher level than the input. Proper timing and control of switches ensure efficient charge transfer while minimizing losses.

IV. CIRCUIT DIAGRAM

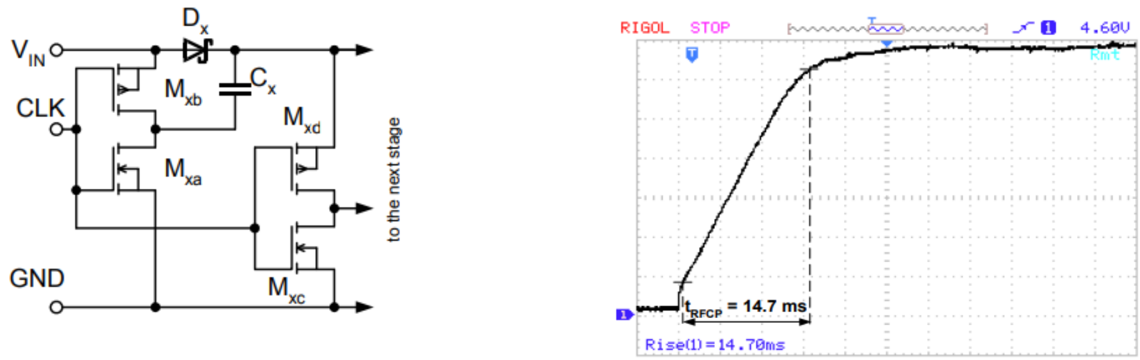

Figure 1. The one stage of the original FCP structure [6].

Fig. 1:Fibonacci Charge Pump with sample output waveform

The circuit diagram of a single-stage Fibonacci charge pump (FCP) features a combination of MOSFET switches, a Schottky diode, and a flying capacitor, synchronized by an external clock signal. The input voltage (VIN*VIN*) is applied at the source, with the Schottky diode Dx*Dx* and the flying capacitor Cx*Cx* positioned to transfer charge in a controlled manner MOSFETs Mxa*Mxa*, Mxb*Mxb*, Mxc*Mxc*, and Mxd*Mxd* act as switches, toggled by the clock signal (CLK) to orchestrate the charge and discharge cycles essential for voltage multiplication. During one portion of the clock cycle, switches are configured so that the flying capacitor Cx*Cx* charges from the input voltage through Dx*Dx* and selected MOSFETs. In the opposite half-cycle, the switches realign, allowing the charged capacitor to transfer its energy to the next stage, supporting the step-wise voltage boosting principle of the FCP

V. PROPOSED SYSTEM

The proposed system introduces a single-stage Fibonacci charge pump (FCP) circuit implemented using eSim software. This circuit aims to demonstrate the voltage multiplication capability based on Fibonacci sequence stages, providing higher voltage gain with fewer stages compared to traditional charge pumps. The FCP structure uses MOSFET switches, Schottky diodes, and flying capacitors controlled by clock signals to transfer and boost charge efficiently. The system replicates the original FCP design to study its operation, voltage build-up, and efficiency characteristics through transient simulations in eSim. This approach offers practical insights into low-power voltage boosting techniques suitable for integrated circuits and energy harvesting applications.

eSIM CIRCUIT

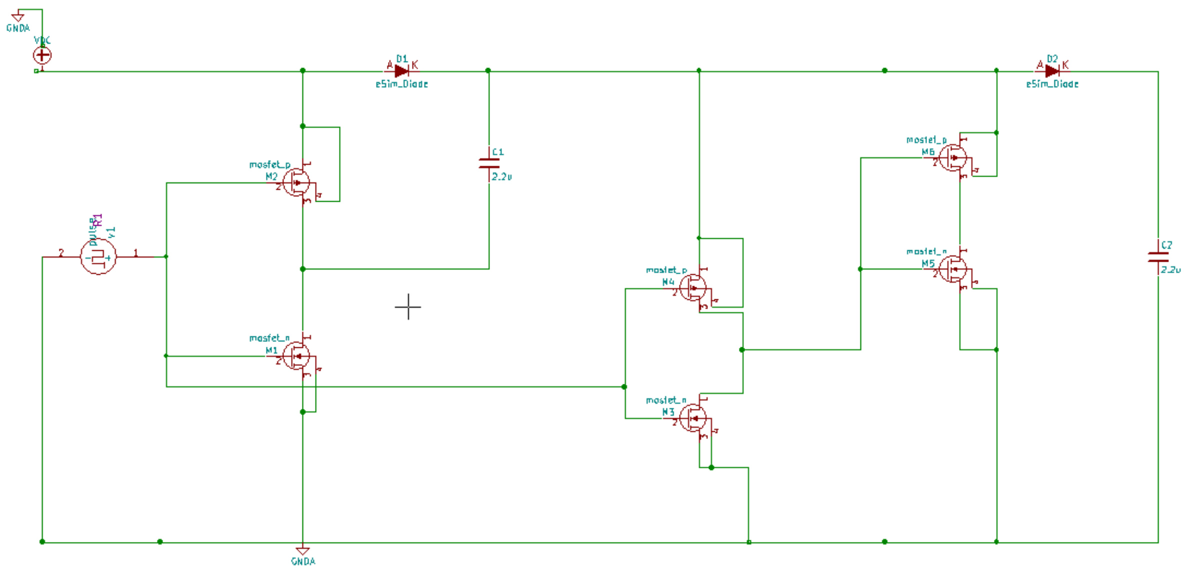

Fig. 2: Fibonacci Charge Pump Circuit in eSim

The proposed system implements a single-stage Fibonacci charge pump circuit within the eSim software environment. Key components include MOSFET switches arranged as active switches, a Schottky diode for unidirectional current flow, and a flying capacitor for energy storage and transfer. The switches are driven by complementary clock signals to alternate between charging the capacitor from the input voltage and transferring the stored charge to the output. This switching sequence leverages the Fibonacci number-based stage gain to multiply voltage efficiently. The design aims to demonstrate stable voltage boosting and efficient charge transfer in a compact configuration suitable for low-power applications.

OUTPUT WAVEFORM

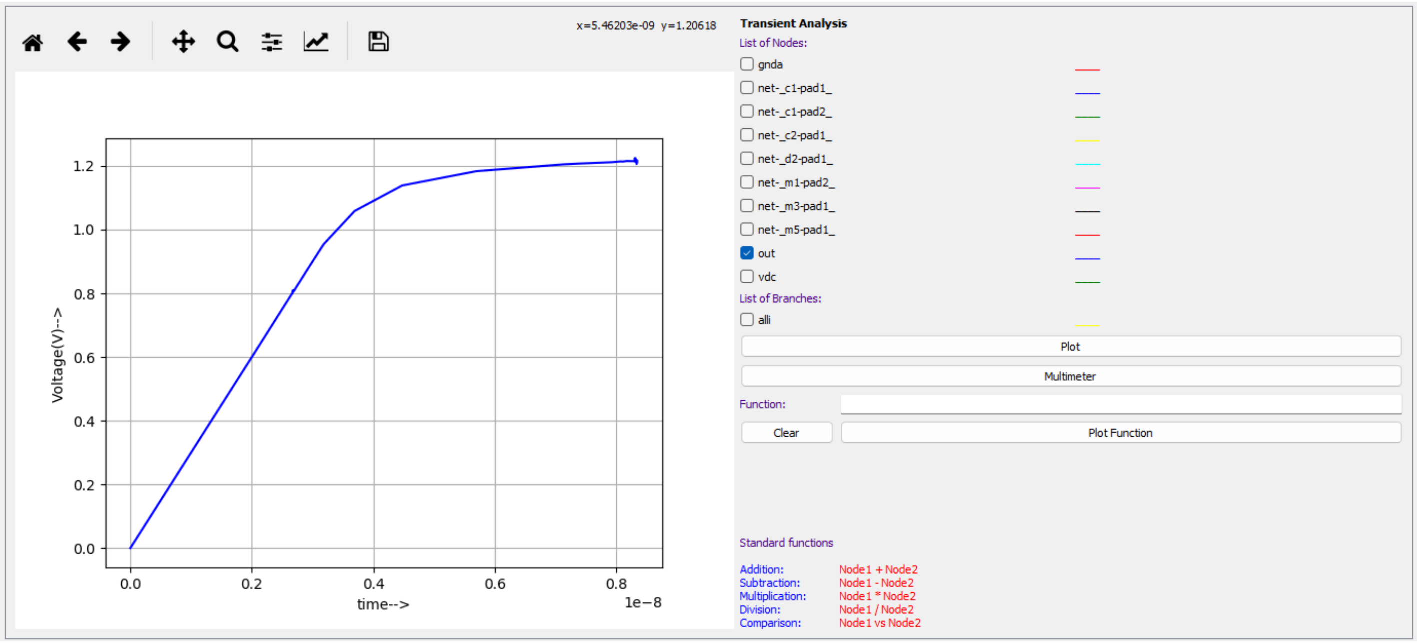

Fig. 3: Output Waveform Fibonacci Charge Pump Circuit in Esim

Figure 3 showcases the output waveform of the Fibonacci Charge Pump circuit simulated using eSim software. The blue waveform represents the Volatge vs Time curve as given in the reference output waveform of orginal circuit

VI. CONCLUSION

The project successfully demonstrates the design and simulation of a single-stage Fibonacci charge pump using the eSim platform. The FCP architecture, based on Fibonacci-number stage gains, achieves efficient voltage multiplication with fewer stages compared to conventional charge pumps. Simulation results show a progressive increase in output voltage with relatively stable and smooth waveforms when appropriate component values and simulation parameters are chosen. The project highlights the importance of proper MOSFET and diode selection, clock timing, and circuit configuration to minimize power losses and improve efficiency. Challenges such as convergence issues and timestep errors were addressed by optimizing simulation settings and adding small series resistances. Overall, the Fibonacci charge pump proves to be an effective topology for compact, low-power voltage boosting applications, offering promising potential in integrated circuit designs and energy harvesting systems.

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