DC-DC Voltage Multiplier Using Dickson Charge Pump Topology

Pravin A
Dept of Electronics and Communication Engineering
Sri Eshwar College of Engineering, Coimbatore

Abstract

This paper explores the operational principles and applications of Dickson charge pump circuits implemented with diodes and capacitors. Dickson charge pumps, a form of switched-capacitor voltage multiplier, are fundamental in power management systems, crucial for voltage boosting, negative voltage generation, and compact DC–DC conversion. The study examines both positive and negative voltage configurations, highlighting the role of clock phases, diode orientation, and capacitor sizing in determining performance. The abstract emphasizes the significance of charge pumps in low-power electronics, such as RFID, IoT devices, and on-chip power supplies, where inductorless solutions are preferred for integration efficiency. Simulation of Dickson charge pump circuits using the open-source eSim software, with comparisons to theoretical expectations, provides a practical understanding of their functionality and limitations. Overall, this paper contributes to a detailed understanding of charge pumps and their applications in modern electronic systems, leveraging simulation tools for analysis and optimization.

Keywords:Charge Pump, Voltage Multiplier, Dickson Charge Pump, DC-DC Converter, Voltage Gain

I. INTRODUCTION

A Dickson charge pump is a fundamental circuit in power electronics, widely used for voltage multiplication and generation of higher or negative supply voltages without the need for inductors. When implemented with diodes and capacitors, it offers advantages of simplicity, compactness, and suitability for integration in CMOS technologies. The Dickson charge pump consists of multiple stages, each comprising a diode–capacitor pair, driven by two non-overlapping clock signals to transfer charge step by step. In its simplest form, the circuit boosts the input voltage by stacking charge across successive stages, making it capable of producing output voltages greater than the input or even generating negative voltages depending on configuration. The output remains steady once capacitors are charged, but its value depends on parameters such as input supply, diode threshold voltage, capacitor size, load resistance, and clock frequency.

II. PURPOSE OF DICKSON CHARGE PUMP

The primary purpose of the Dickson charge pump is to generate output voltages higher or lower (negative) than the available supply without relying on bulky inductors or transformers. This makes it an efficient and compact solution for on-chip voltage generation in integrated circuits. By using a combination of diodes (or diode-connected MOSFETs), capacitors, and clock signals, the Dickson charge pump transfers charge stage by stage to multiply or invert the input voltage. It is widely employed in low-power and space-constrained applications such as EEPROM and Flash memory programming, LCD drivers, RFID tags, and IoT devices where multiple voltage levels are required from a single supply source. The design also provides advantages in terms of easy CMOS integration, reduced cost, and suitability for energy-harvesting systems. Overall, the Dickson charge pump serves as a reliable inductorless DC–DC converter, offering versatility in both portable electronics and VLSI circuits

III. WORKING PRINCIPLE

The Dickson charge pump works on the principle of transferring charge through diodes and capacitors using clock pulses. It has two non-overlapping clock signals that alternately charge and discharge capacitors, pushing charge step by step from the input toward the output.

- When the first clock goes high, a capacitor charges up through a diode.
- When the clock switches low, the stored charge is pushed forward to the next stage.
- At the same time, the second clock helps the next capacitor to charge and transfer charge further along the chain.
- By repeating this process across multiple stages, the voltage keeps adding up stage by stage.
- Finally, at the output, the voltage is much higher (or inverted in case of a negative pump) compared to the input supply.

IV. CIRCUIT DIAGRAM

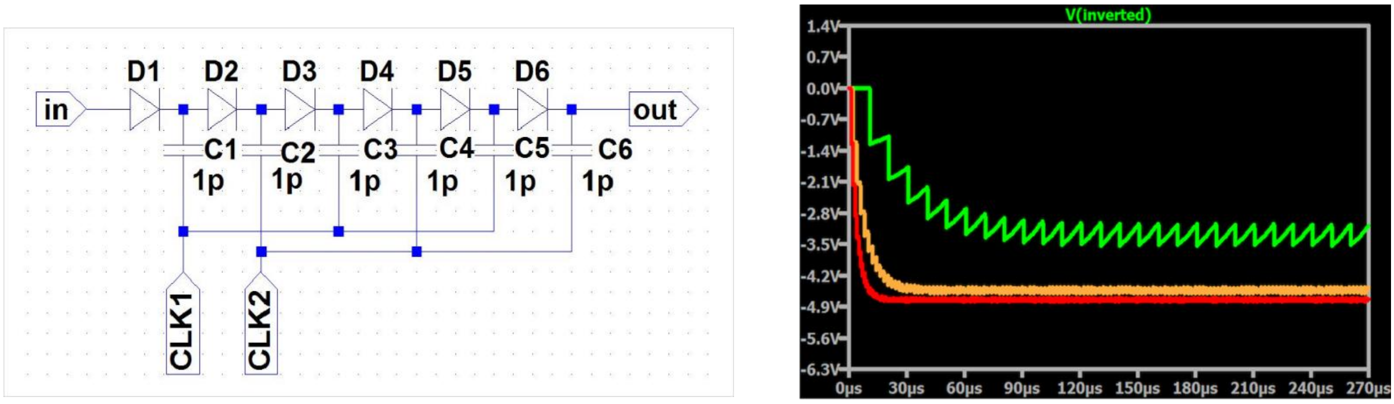

Fig. 1: Dickson charge pump with sample output waveform

The input waveform is a constant DC supply that provides the base voltage for the circuit. The clock waveforms are periodic pulses that drive the pumping capacitors and enable charge transfer between stages. At the intermediate nodes, the voltages rise in steps, following the charging and discharging action of the capacitors. The output waveform shows an initial rise as the capacitors charge and then settles to a steady boosted DC voltage higher (inverted) than the input

V. Proposed System

The proposed system introduces a Dickson charge pump circuit implemented using eSim software. This circuit aims to demonstrate the functionality of an inductorless DC–DC converter capable of boosting or inverting voltage levels. The Dickson charge pump, based on diodes and capacitors driven by clock signals, serves the purpose of generating higher or negative supply voltages from a low input source. It effectively transfers charge stage by stage, ensuring compact voltage multiplication suitable for integrated systems.

eSIM CIRCUIT

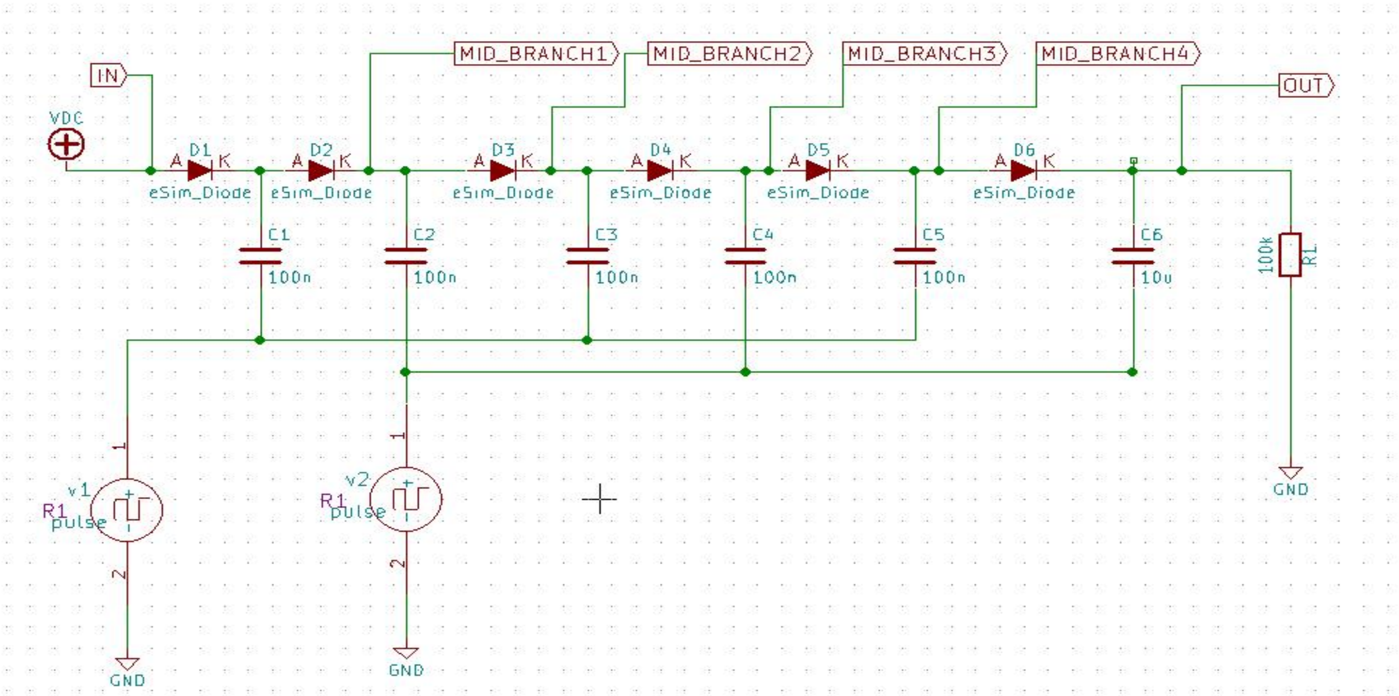

Fig. 4: Dickson Charge Pump Circuit in eSim

The circuit consists of a series of diode–capacitor stages driven by two out-of-phase clock signals. Each stage transfers charge forward, gradually increasing or inverting the voltage relative to the input supply. At the output, the accumulated charge provides a boosted or negative DC voltage suitable for low-power applications.

OUTPUT WAVEFORM

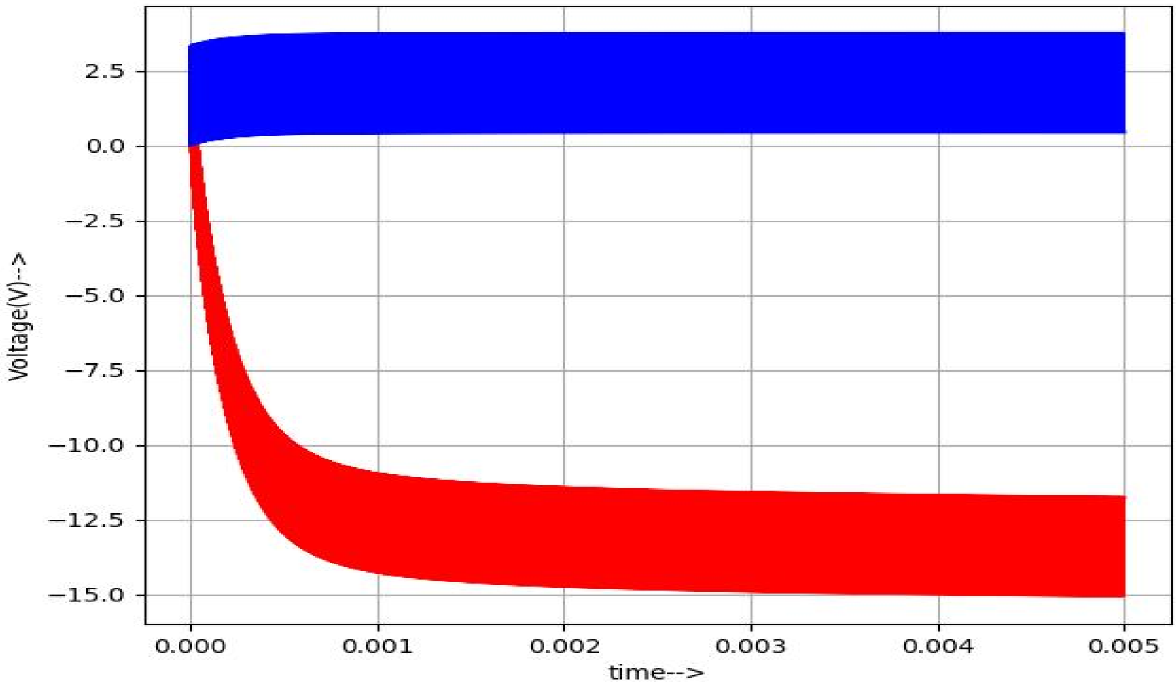

Fig. 5: Output Dickson Charge Pump Circuit in eSim

Fig. 5 shows the single-output waveform of the charge pump, where the voltage starts with a transient response as the capacitors charge and then settles to a steady boosted (inverted) DC voltage. This demonstrates the charge transfer mechanism where each stage contributes to the final output potential.

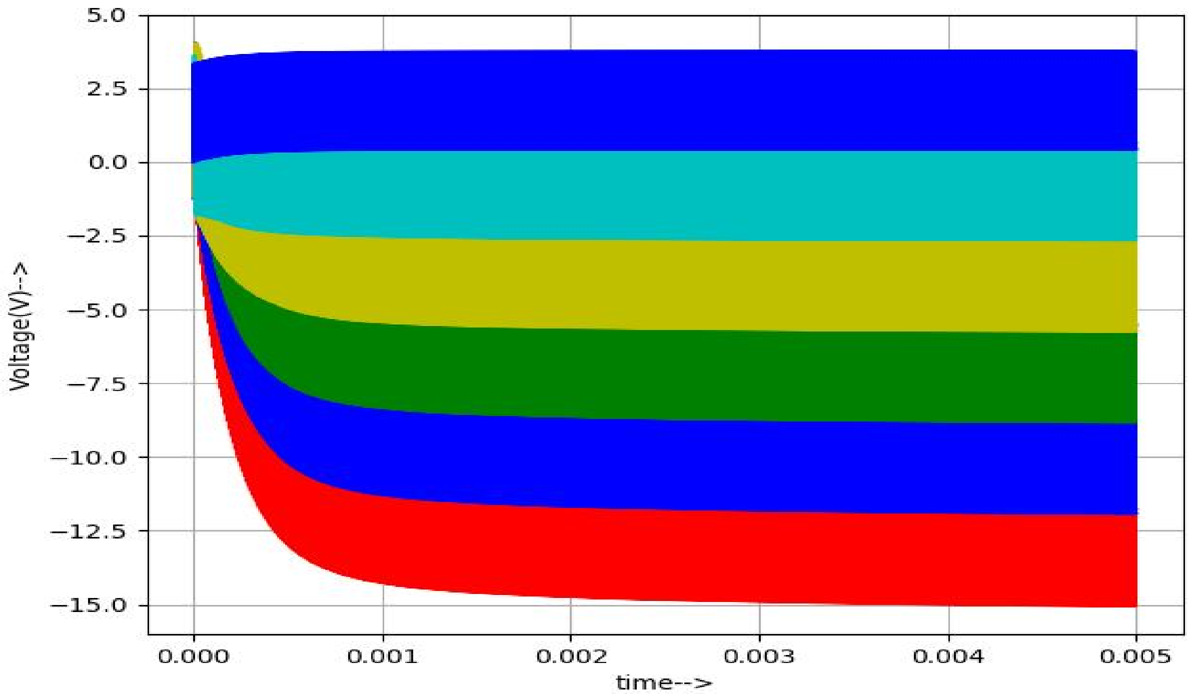

Fig. 6: Output Dickson Charge Pump Circuit in eSim (Stage-by-Stage Output Waveform)

Fig. 6 depicts the stage-by-stage voltage development across the intermediate nodes of the circuit. Each colored trace corresponds to a different diode–capacitor stage, clearly showing the progressive voltage drop or boost as charge is transferred forward. The stepped voltage profile confirms the proper functioning of the multi-stage charge pump, where each successive node provides either an incrementally higher positive voltage or a further inverted negative voltage depending on configuration.

VI.CONCLUSION

In this study, we explored the design and simulation of a Dickson charge pump circuit using eSim. The Dickson charge pump, based on diode–capacitor stages driven by clock signals, plays a vital role in power management by enabling voltage boosting and inversion without inductors. It provides an efficient method for generating higher or negative supply voltages from a single low-voltage source. Through simulation in eSim, we gained valuable insights into the charge pump's charging process, stage-wise voltage multiplication, and steady-state behavior. eSim served as an effective platform for designing and analyzing the circuit, offering a clear understanding of its practical characteristics in both transient and steady condition

VII. REFERENCE

1) *Design Analysis of Dickson Charge Pump in 90nm Technology* — Research Publish Journals. LINK
2) Dickson, J. F. (1976). "On-chip high-voltage generation in MNOS integrated circuits using an improved voltage multiplier technique." *IEEE Journal of Solid-State Circuits*, 11(3), 374–378.
3) Sergio Franco. *Design with Operational Amplifiers and Analog Integrated Circuits*, 4th Edition. McGraw-Hill Education, 2014.
4) Adel S. Sedra and Kenneth C. Smith. *Microelectronic Circuits*, 7th Edition. Oxford University Press, 2015.
5) Razavi, B. (2017). *Design of Analog CMOS Integrated Circuits*. 2nd Edition. McGraw-Hill Education.
6) Kang, Sung-Mo, and Yusuf Leblebici. *CMOS Digital Integrated Circuits: Analysis and Design*, 3rd Edition. McGraw-Hill, 2003