DICKSON CHARGE PUMP CIRCUIT

LINGESHWARAN S

Email: lingeshwaran1842007@gmail.com

BANNARI AMMAN INSTITUTE OF TECHNOLOGY-TAMILNADU

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

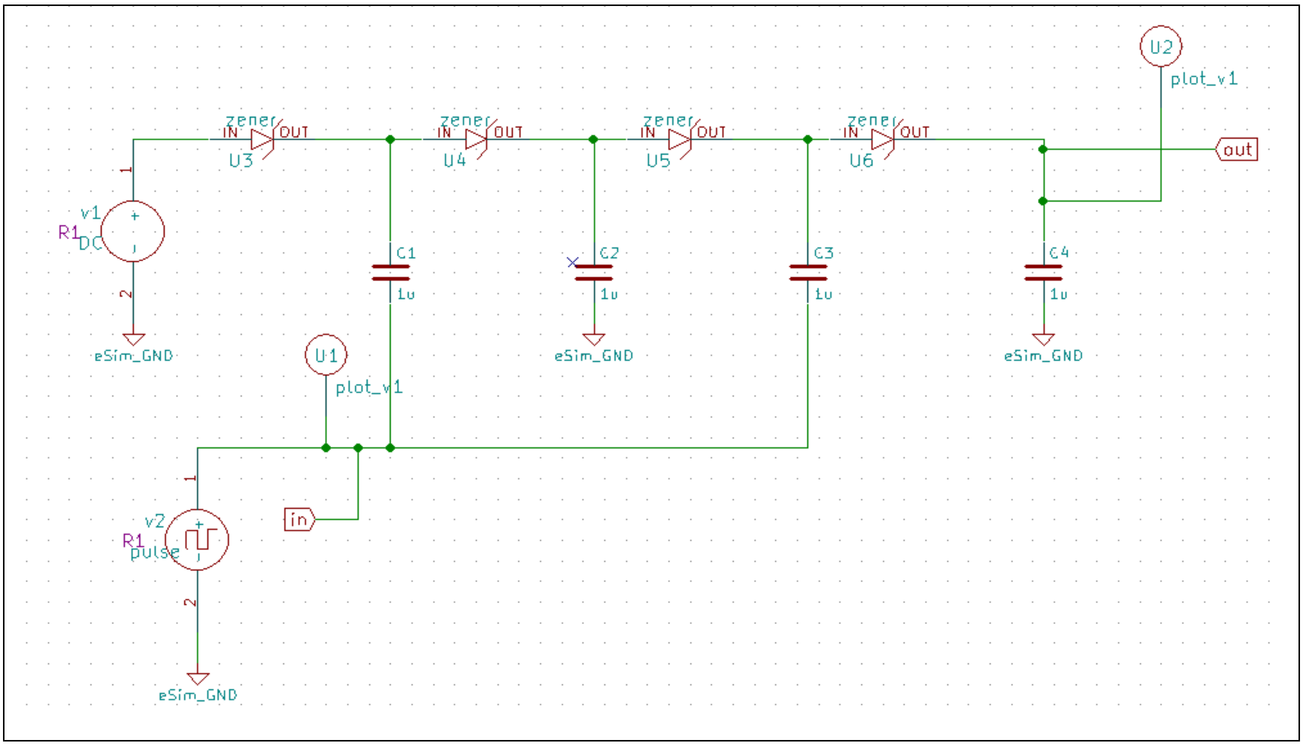
INTRODUCTION:

A Dickson charge pump is a type of voltage multiplier circuit that efficiently converts a lower DC voltage into a higher DC voltage using only diodes and capacitors as its main components. It operates on the principle of charge transfer, where capacitors are alternately charged and discharged through diodes under the control of a clock or switching signal. This circuit eliminates the need for inductors, making it highly suitable for integrated circuit (IC) implementation and compact power supply designs.

The Dickson charge pump provides advantages such as simple structure, low cost, and ease of integration, while delivering moderate efficiency for low to medium current loads. It is widely used in flash memory programming, EEPROMs, LCD bias generation, and RS-232 level shifters (like MAX232 ICs).

Typical characteristics include high voltage gain per stage, low ripple voltage, small size, and reliable DC conversion. Since the input to the Dickson charge pump is generally a low DC or pulsed signal, it is particularly useful in low-power electronic and energy-harvesting systems where compactness, stability, and efficiency are essential.

SCHEMATIC DIAGRAM:



TRANSIENT RESPONSE ANALYSIS:

PARAMETERS:

1.All the capacitors used in the circuit have a value = 1micro farad.

2.The input (DC) V1 is set at 5V.

3.The trigger(pulse) is set at 5V.

4.The output signal is observed across the capacitor(C4).

GENERAL EQUATION:

Ideal RMS Output:

$$\text{Ideal: } V_{out(RMS)} = V_{in} + N \cdot V_{clk(RMS)}$$

- V_{in}= DC input
- N= number of stages

- $V_{clk(RMS)}$= RMS of AC clock pulse

Key Point:

The practical RMS output is usually less than the calculated ideal value. It approaches the ideal only with large capacitors, high frequency clocks, and low load current.

- $V_{in} = 5$ V, $V_{clk(RMS)} = 3.5$ V.
- $N = 4, V_D = 0.7$ V, $C = 1\ \mu F$ load.

$$V_{out(RMS)} \approx 16.2 \text{ V (ideal without load drop)}$$

- With 1 µF load → **practical RMS drops to ~12.6 V**
- Output rises gradually → **takes several clock cycles** to reach steady RMS

SIMULATION OUTPUT:

Ngspice plot-input:

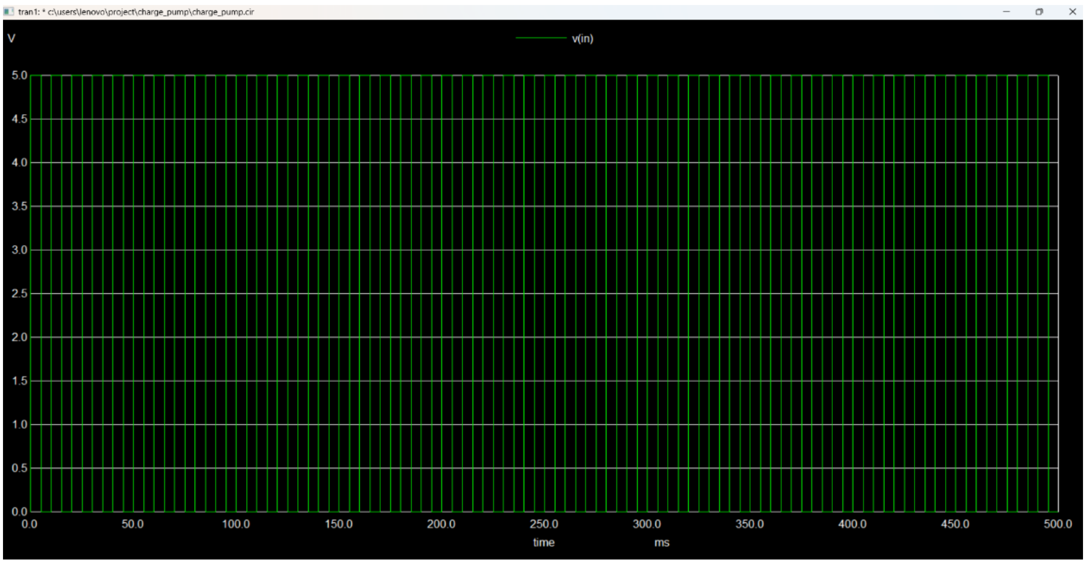


Figure 1. Pulse(5V), RMS=3.5V.

<u>Ngspice plot-output:</u>

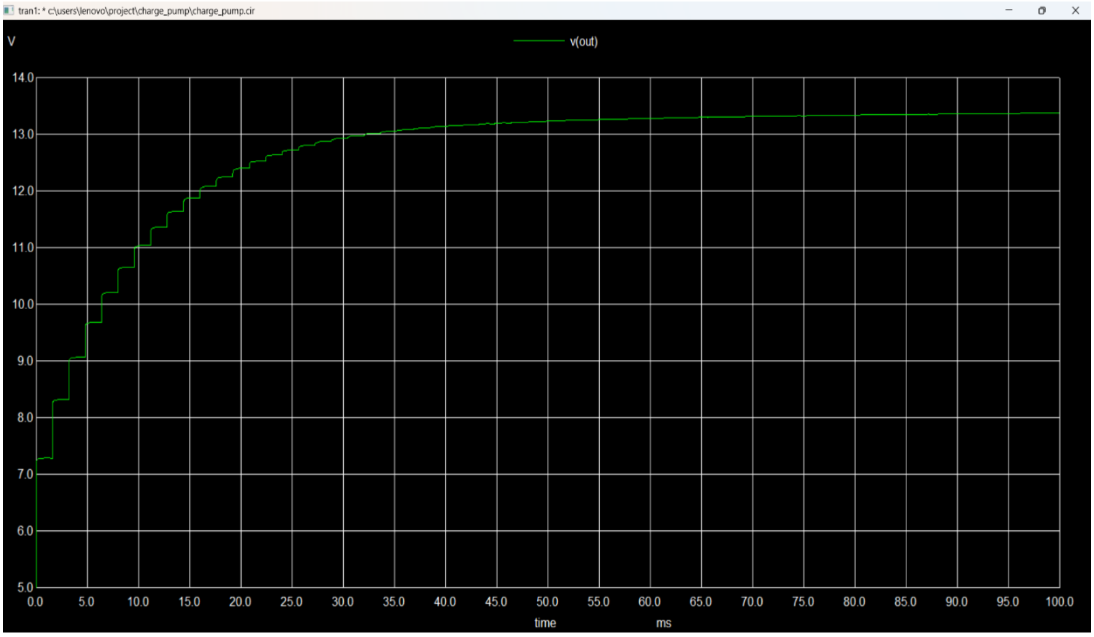
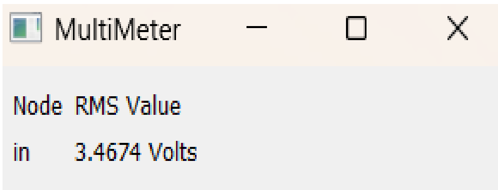
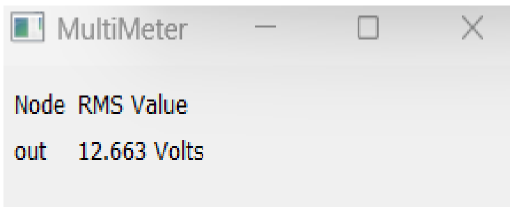


Figure 2. Output plot

<u>INPUT Vpulse- in RMS:</u>

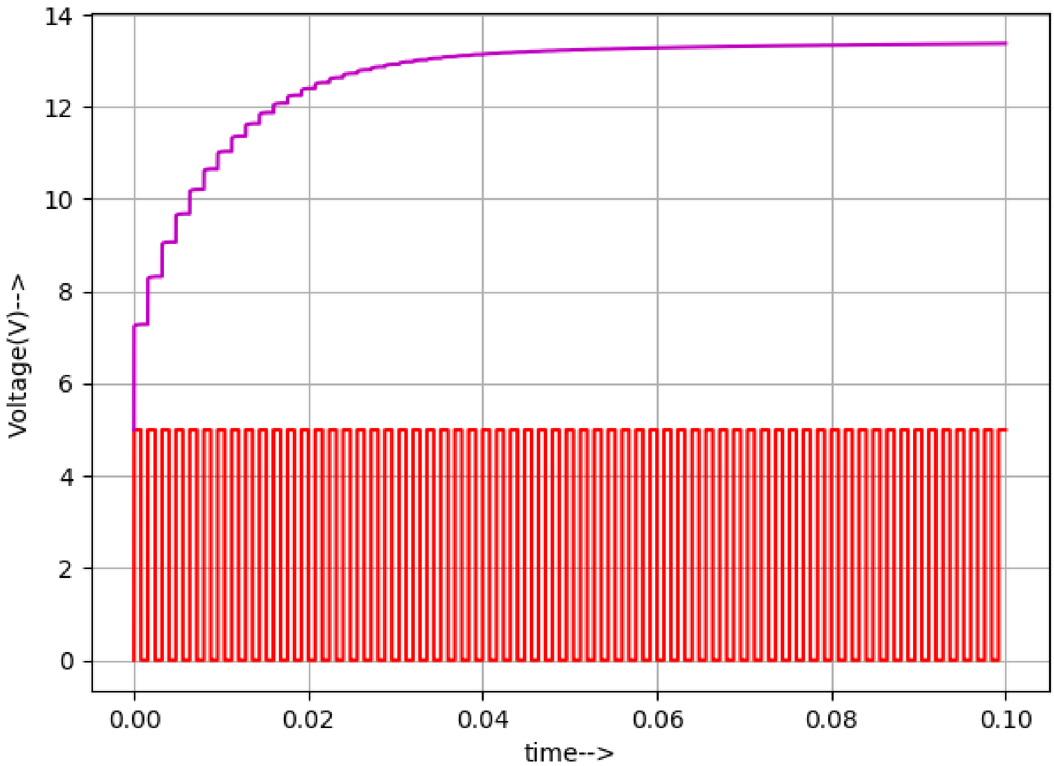


<u>OUTPUT RMS VALUE:</u>



The output increases because the charge pump transfers charge from the AC clock pulses to the capacitors stage by stage, stacking the voltage. Each stage adds part of the AC RMS voltage (minus diode drops) to the previous stage, so the final output builds up from the input 5 V DC + 3.56 V RMS clock to 12.6 V RMS.

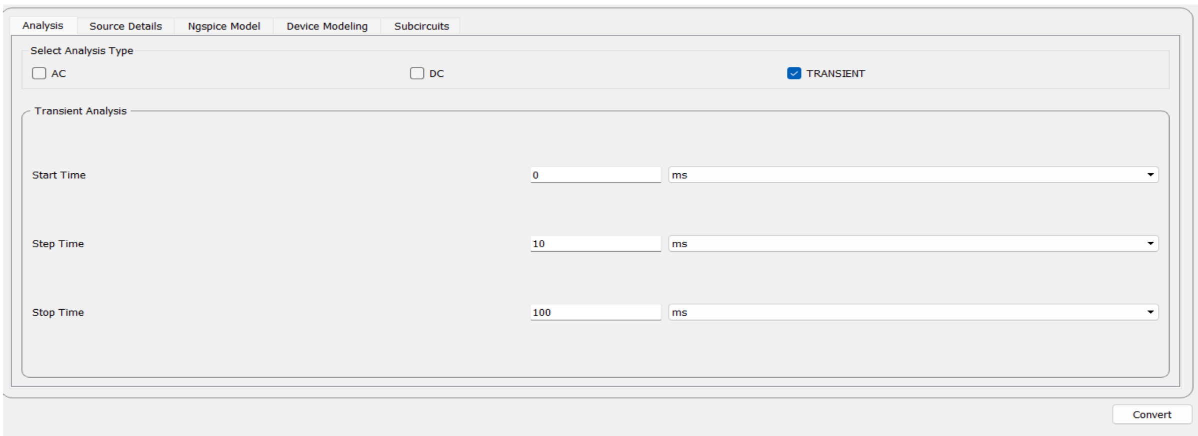
PYTHON PLOT:



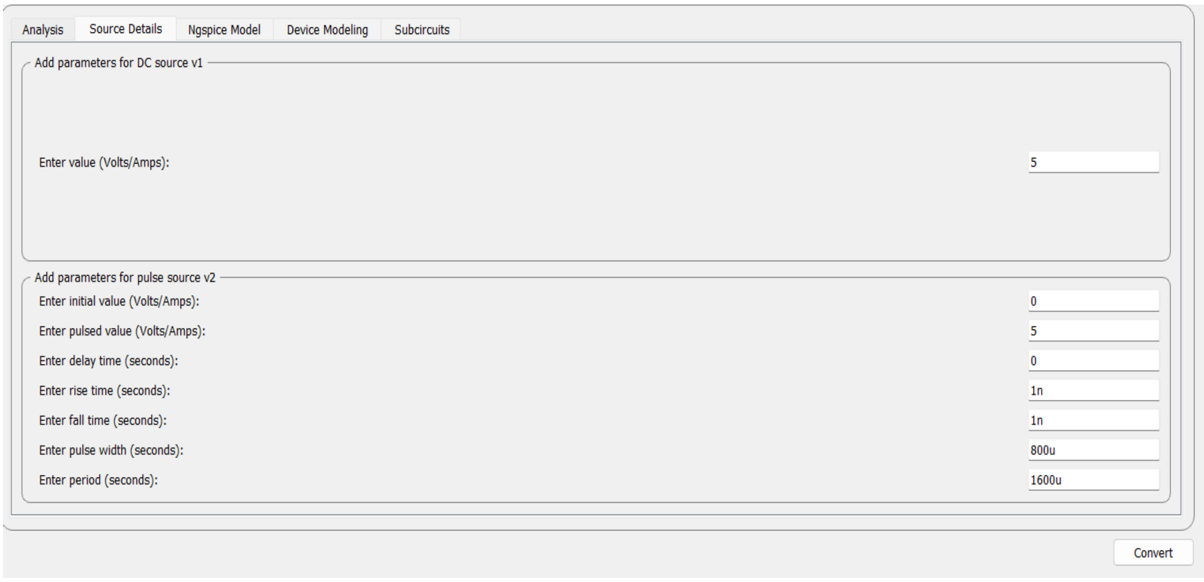
RED- PULSE PROVIDED.

PURPLE-OUTPUT.

TRANSIENT ANALYSIS:



SOURCE DETAILS:



CONCLUSION:

1. **Voltage Boosting:** The charge pump effectively increases the DC voltage by stacking AC clock contributions stage by stage.
2. **RMS Behaviour:** Output RMS voltage depends on the input DC, AC clock RMS, number of stages, diode drops, and load.
3. **Transient Response:** Output rises gradually from the input voltage to steady-state due to capacitor charging; rise time depends on capacitance and switching frequency.
4. **Practical vs Ideal:** Practical output is lower than the ideal calculation because of diodes voltage drops, limited capacitor size, and load effects.

5. **Load and Frequency Effects:** Increasing stage capacitance or clock frequency improves the output voltage closer to the calculated value.
6. **Stage Contribution:** Each stage adds a portion of the AC clock to the output; more stages give higher output but also increase losses.
7. **Application:** Charge pumps are suitable for generating higher voltages without inductors, useful in low-power ICs, sensors, and biasing circuits.

REFERENCE:

T. Tanzawa and T. Tanaka, "A dynamic analysis of the Dickson charge pump circuit," IEEE - ieeexplore.ieee.org/abstract/document/604079

GITHUB REPOSITORY LINK:

https://github.com/lingeshwaran205/My_eSim_Project

README DISCRIPTION:

Design and Simulation of a 4-Stage Dickson Charge Pump using eSim

Short Description

This project presents the design and simulation of a 4-Stage Dickson Charge Pump using eSim, an open-source EDA tool based on KiCad and NgSpice.
The Dickson Charge Pump is a voltage multiplier that converts a low DC or AC input into a higher DC output using only diodes and

capacitors, driven by clock pulses.
It eliminates the need for inductors and is widely used in:

- On-chip voltage boosters
- EEPROM/Flash programming circuits
- Low-power DC–DC converters

Objective

To design and simulate a 4-stage Dickson Charge Pump capable of stepping up an input voltage of approximately 3.4674 V (RMS) to an output voltage of around 12.663 V (RMS) using eSim.

Software / Tools Used

- eSim (KiCad + NgSpice) – for schematic design and simulation
- NgSpice – for transient and steady-state analysis
- KiCad component libraries – for diode and capacitor modeling

---

Circuit Description

The circuit consists of four pumping capacitors and four diodes connected in a cascaded arrangement.
Each stage transfers charge during alternate clock cycles.
When the clock toggles, the capacitors charge and discharge sequentially through the diodes, stacking voltage at each node.

For a 4-stage configuration, the theoretical output can be estimated by:

$V_{out} \approx V_{in} + (n \times V_{clk}) - (n \times V_d)$ where

- $n = 4$

- (V_{clk}) is the clock amplitude
- (V_d) is the diode forward voltage drop

Measured Simulation Results

Parameter	Value
Input Voltage (RMS)	3.4674 V
Output Voltage (RMS)	12.663 V
Voltage Gain	≈ 3.65×

The simulation verifies that the Dickson Charge Pump successfully multiplies the input voltage through four charge-transfer stages.

How to Run / Reproduce

1. Download and unzip esimproject.zip.
2. Open the schematic file dickson_charge_pump_4stage.sch in eSim.
3. Ensure the input source and clock parameters match the given conditions.
4. Run the NgSpice simulation to view the transient response.
5. Measure RMS voltage values at input and output nodes.
6. Compare results with theoretical predictions.

Repository Contents

File	Description
LICENSE	GPL v3 license file
README.md	Project description and instructions
eSimReport.pdf	Detailed project report with circuit, results, and conclusions
esimproject.zip	Compressed project files (schematic, netlist, simulations, etc.)

Applications

- On-chip voltage boosters
- Flash memory and EEPROM programming circuits
- Sensor bias generation
- Low-power charge-pump circuits

🧾 Contributor

Lingeshwaran
Project: *Design and Simulation of a 4-Stage Dickson Charge Pump using eSim*