Design and Simulation of High Voltage DCSource by Using Cockcroft Walton Voltage Multiplier

Tharun. D
Dept of Electronics and Communication Engineering
SRM Institute of Science and Technology, Ramapuram

Abstract

This paper presents the design, operation, and practical applications of the Cockcroft–Walton voltage multiplier circuit, a widely used solution for generating high DC voltages from low-voltage AC sources. By employing a cascaded network of capacitors and diodes, the circuit efficiently multiplies the input voltage through successive charging and discharging cycles, achieving high voltage output without the need for bulky transformers. The study explains the working principle of each stage, analyzes the effects of load resistance and frequency on voltage regulation, and compares the performance to other voltage boosting techniques. Simulations conducted in eSim validate the circuit's capability to deliver stable high-voltage output with minimal ripple for light to moderate loads. Owing to its simple construction, cost-effectiveness, and ability to achieve high voltage levels, the Cockcroft–Walton multiplier finds applications in particle accelerators, X-ray machines, photomultiplier tubes, and various high-voltage testing equipment. This work highlights the relevance of multiplier-based designs in modern high-voltage generation systems where efficiency, scalability, and simplicity are essential.

Keywords: Voltage multiplier, Cockcroft–Walton circuit, High-voltage generation

I. INTRODUCTION

A Cockcroft–Walton voltage multiplier circuit is designed to generate high DC voltages from a relatively low-voltage AC input, using a cascaded arrangement of capacitors and diodes. Through sequential charging and discharging of the capacitors, the circuit effectively multiplies the input voltage over multiple stages, delivering a significantly higher output without the need for bulky step-up transformers. Its simple, transformerless design makes it compact, cost-effective, and highly efficient for light to moderate load conditions. The low component count and scalability allow easy adjustment of output voltage by adding or removing stages. This makes the Cockcroft–Walton multiplier especially valuable in applications such as particle accelerators, X-ray generators, photomultiplier tubes, and high-voltage testing equipment, where stable high voltage is required. By providing a reliable means of voltage multiplication with minimal ripple under proper design, this circuit ensures dependable operation, extended equipment lifespan, and versatility in modern high-voltage systems.

II. PURPOSE OF COCKCROFT–WALTON VOLTAGE MULTIPLIER

The Cockcroft–Walton voltage multiplier circuit serves several essential purposes in high-voltage generation systems:

- **High-Voltage Generation from Low Input:** It enables the conversion of a relatively low-voltage AC input into a much higher DC voltage, eliminating the need for bulky and expensive high-voltage transformers.
- **Cost-Effective and Compact Design:** Its simple arrangement of capacitors and diodes allows for lightweight, low-cost construction, making it suitable for portable and space-limited applications.
- **Scalability:** The output voltage can be easily adjusted by adding or removing stages, providing flexibility for different voltage requirements in various applications.
- **Reliable Performance in Light-Load Conditions:** It delivers stable, ripple-minimized high-voltage output when designed for appropriate load conditions, ensuring dependable operation in scientific, medical, and industrial equipment.

III. WORKING PRINCIPLE

The working principle of a Cockcroft–Walton voltage multiplier is based on the sequential charging and discharging of capacitors through diodes to progressively increase the DC output voltage from an AC input source. Here are the key steps in its operation:

1. Input AC Voltage Application: When an alternating voltage is applied to the circuit, the diodes and capacitors are arranged in such a way that during each half-cycle, specific capacitors are charged to the peak AC voltage.
2. Charging During Positive Half-Cycle: In the positive half of the AC input, certain diodes become forward-biased, allowing current to flow and charge the corresponding capacitors to the peak voltage value.
3. Charging During Negative Half-Cycle: In the negative half of the AC input, a different set of diodes conducts, transferring the charge from previously charged capacitors to the next stage, effectively stacking the voltages.
4. Voltage Multiplication: As the process repeats over multiple AC cycles, each stage adds to the total output voltage. The output voltage is approximately equal to twice the peak input voltage multiplied by the number of stages, minus small drops due to diode forward voltage and load effects.
5. Stable High-Voltage Output: Under light-load conditions, the output voltage remains nearly constant with minimal ripple. However, heavy loads can cause voltage sag due to capacitor discharge between cycles, which can be minimized by using larger capacitors or higher operating frequencies.
6. Practical Applications: This principle makes the circuit ideal for generating high DC voltages in applications such as particle accelerators, X-ray generators, electrostatic equipment, and high-voltage testing devices.

CIRCUIT DIAGRAM

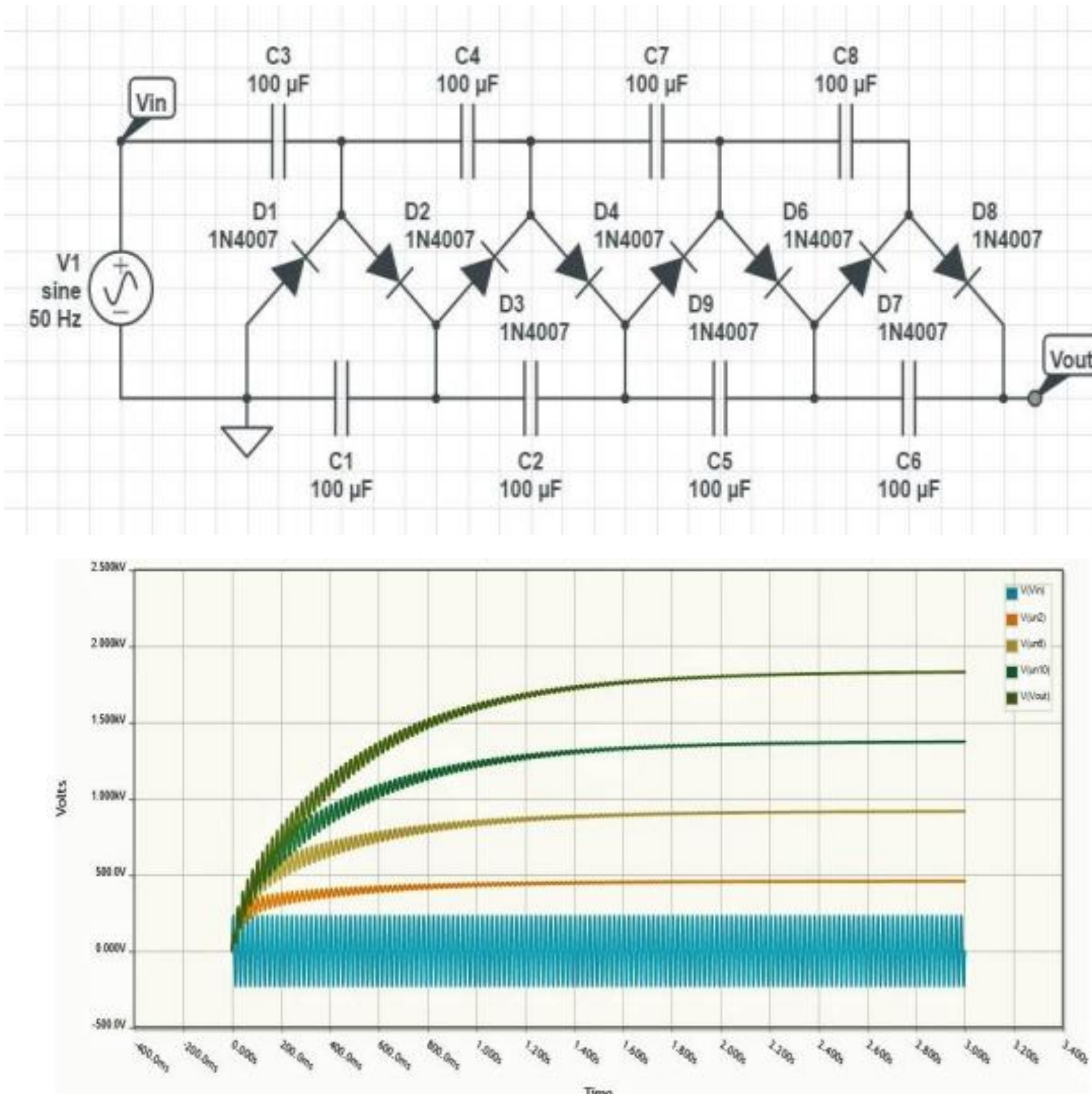

Fig.1: Cockcroft–Walton voltage multiplier

The Cockcroft–Walton voltage multiplier circuit uses a cascaded arrangement of capacitors and diodes to efficiently convert a low-voltage AC input into a much higher DC output. In this design, the capacitors are charged in sequence during alternating half-cycles of the input waveform, with the diodes directing current flow to progressively stack the voltages. Each stage adds to the total output, allowing the circuit to achieve high voltage levels without the need for large and costly step-up transformers. Under correct operation, the multiplier provides a stable high-voltage output with minimal ripple for light-load conditions. If the load increases, output voltage may drop due to capacitor discharge, which can be reduced by using larger capacitance values or higher input frequencies. This arrangement offers a compact, cost-effective, and scalable high-voltage generation method, making it widely applicable in particle accelerators, X-ray equipment, photomultiplier tubes, and various high-voltage testing systems.

IV. PROPOSED SYSTEM

The proposed system presents a Cockcroft–Walton voltage multiplier circuit implemented using eSim software. This circuit is designed to demonstrate efficient high-voltage generation from a low-voltage AC input using a cascaded network of capacitors and diodes. By sequentially charging and stacking voltages across multiple stages, the circuit achieves a significantly higher DC output without the need for bulky step-up transformers, making it compact and cost-effective. Its simple design allows for easy scalability by adding or removing stages, enabling customization for various voltage requirements. The simulation results highlight the circuit's ability to provide stable high-voltage output under light-load conditions, with minimal ripple and good efficiency. This makes the system ideal for applications such as particle accelerators, X-ray machines, photomultiplier tubes, and other high-voltage testing and research equipment where reliability, efficiency, and compact design are essential.

eSIM CIRCUIT

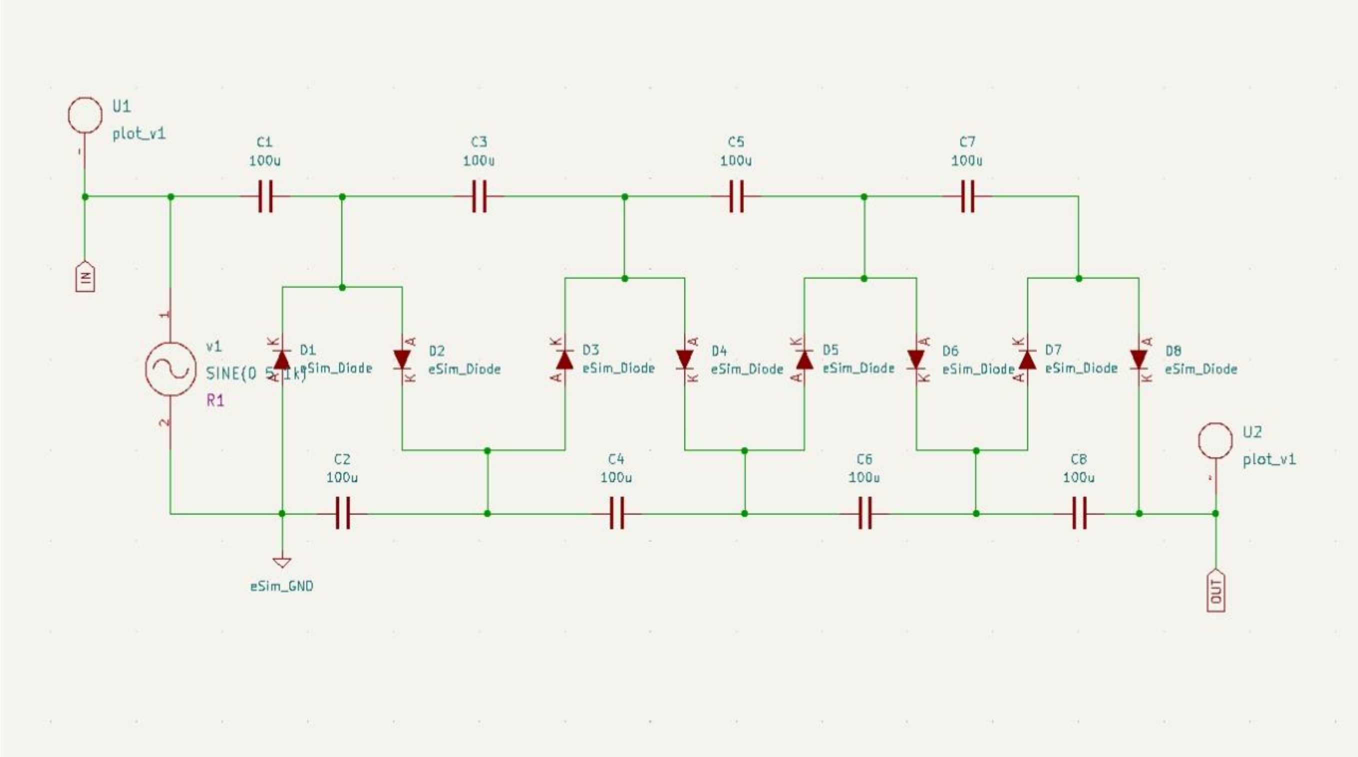

Fig.2: Cockcroft–Walton voltage multiplier circuit in eSIM

Figure 2 presents the circuit diagram of a Cockcroft–Walton voltage multiplier designed within the eSim software environment. The circuit consists of a cascaded network of capacitors and diodes arranged in multiple stages to progressively increase the output voltage from a low-voltage AC input. During each half-cycle of the AC waveform, specific diodes conduct to charge the capacitors, while in the alternate half-cycle, stored charges are transferred and stacked, resulting in a multiplied DC output voltage. The number of stages directly determines the achievable output voltage, with each stage adding approximately twice the peak input voltage minus diode losses. This configuration eliminates the need for bulky high-voltage transformers, offering a lightweight, cost-effective, and easily scalable solution for high-voltage generation. Such an arrangement is well-suited for applications including particle accelerators, X-ray generators, photomultiplier tubes, and high-voltage testing equipment where efficiency, compact design, and reliable performance are essential.

OUTPUT WAVEFORM

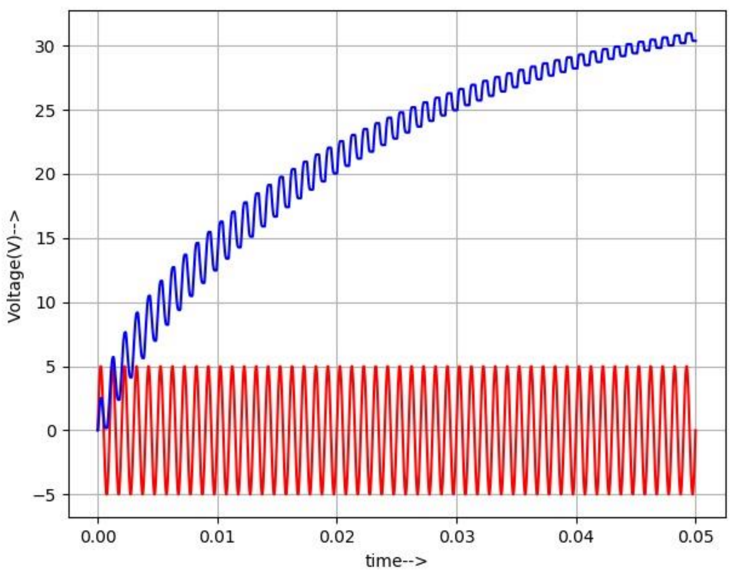

Fig.3:Output Waveform Cockcroft–Walton voltage multiplier circuit in eSIM

Figure 3 showcases the output waveform of the Cockcroft–Walton voltage multiplier circuit simulated using eSim software. The graph illustrates the voltage multiplication process over time as the capacitors charge through successive AC cycles. The red trace represents the input AC voltage, while the yellow trace represents the multiplied DC output voltage. As the simulation begins, the yellow trace gradually rises in stepped increments, corresponding to the charging of each stage in the multiplier network. After a few cycles, the output stabilizes at a high DC voltage level, significantly greater than the peak input voltage, confirming the effective voltage multiplication. Minor ripple can be observed on the output waveform, which is typical of such circuits and can be reduced by increasing capacitor values or operating frequency.

Key observations from the graph:

1. Gradual Voltage Build-Up: The yellow trace shows a stepped rise in voltage during the initial cycles, indicating the sequential charging of capacitors in each stage of the multiplier.
2. Effective Voltage Multiplication: The final steady-state output voltage is significantly higher than the peak of the red input trace, confirming the successful multiplication effect of the cascaded capacitor–diode network.
3. Stable High-Voltage Output: Once fully charged, the output voltage remains stable with minimal ripple under light-load conditions, demonstrating reliable performance of the circuit.

In summary, this waveform demonstrates that the Cockcroft–Walton voltage multiplier effectively converts a low-voltage AC input into a stable high-voltage DC output, achieving efficient voltage multiplication with minimal ripple, making it ideal for applications where compact, cost-effective, and reliable high-voltage generation is essential.

Applications of Cockcroft–Walton voltage multiplier

1. • **Particle Accelerators:** Generates the high DC voltages required to accelerate charged particles for scientific experiments and research.
2. • **X-Ray Machines:** Provides the necessary high-voltage supply for X-ray tube operation in medical imaging and industrial inspection systems.
3. • **Photomultiplier Tubes:** Supplies stable high voltage for the operation of light-sensitive detectors used in spectroscopy and radiation measurement.
4. • **Electrostatic Equipment:** Powers electrostatic precipitators, paint sprayers, and other devices requiring strong electrostatic fields.
5. • **High-Voltage Testing Devices:** Delivers adjustable high DC voltages for insulation testing, component breakdown analysis, and laboratory experiments.

VI .CONCLUSION

In conclusion, the design and simulation of a Cockcroft–Walton voltage multiplier circuit using eSim demonstrated its capability to efficiently generate high DC voltages from a low-voltage AC input. By utilizing a cascaded network of capacitors and diodes, the circuit effectively multiplies the input voltage over successive stages, achieving significant voltage gain without the need for bulky step-up transformers. The simulation results confirmed the circuit's ability to provide stable high-voltage output with minimal ripple under light-load conditions, validating its suitability for scientific, medical, and industrial applications. This study highlights the relevance of such multiplier circuits in scenarios where compact design, cost-effectiveness, and reliable high-voltage generation are essential.

REFERENCES

1. https://www.ijareeie.com/upload/2017/march/21_1_Design.pdf
2. https://www.researchgate.net/publication/312511440_A_Comparative_Study_of_Symmetrical_Cockcroft-Walton_Voltage_Multipliers
3. https://www.allaboutcircuits.com/textbook/semiconductors/chpt-3/voltage-multipliers/