



DC Voltage Multiplier for Low Voltage Application

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Abstract: A voltage multiplier is an electronic circuit used to increase the voltage of an input signal without increasing the current, thus earning the name Step-Up Circuit. Combining diodes and capacitors, these circuits convert AC voltages into higher DC voltages through rectification and energy storage. The Cockcroft-Walton and Greinacher circuits are some of the most popular designs, although specialized high-voltage supply solutions are also available. Multiple stages are used in voltage multipliers. Diodes and capacitors enable current flow in one direction and store energy progressively. They are utilized in a wide variety of applications such as power supplies, high-voltage generators, RF systems, battery-operated devices, and solar circuits for compact and efficient voltage solutions. However, there are practical design issues like load resistance and ripple voltage that must be overcome. This paper discusses the theory, configurations, and applications of voltage multipliers with a focus on their importance in modern electronics and energy management in various technical disciplines.

Keywords: DC Voltage Multiplier; PN diode; Capacitor; Low-Power Electronics

1. INTRODUCTION

Achieving high DC voltage from low voltage sources is a key requirement in many electronic applications. Where high voltage and system compactness are required, such as in medical cameras, portable electronics, and renewable energy systems, high DC voltages provide flying solutions effective for Unlike conventional transformers, which work only with alternating current (AC), DC voltage multipliers Basically are designed to increase direct current (DC) voltage without converting it to AC Through heavy transformers and complexity avoided, these circuits offer a lightweight, space-saving option suitable for low-power, high-voltage applications. DC voltage multipliers are primarily composed of a community of capacitors and diodes organized in precise configurations to acquire incremental voltage increases throughout a couple of ranges. Among the most prominent sorts is the Cockcroft-Walton (CW) multiplier, named after physicists John Cockcroft and Ernest Walton, who first applied this circuit in the early Thirties for particle acceleration experiments. The CW multiplier is a ladder-kind network that correctly multiplies voltage in ranges, allowing extensive voltage gains whilst maintaining performance. This topology, extensively adopted in high-voltage programs, has been instrumental in advancing fields consisting of clinical diagnostics, nuclear research, and high-energy physics [1].

The number one benefit of DC voltage multipliers lies in their honest layout, which makes them less difficult to implement and scale as compared to transformer-primarily based solutions. Voltage multipliers are particularly beneficial in gadgets with stringent area constraints, consisting of CRTs (cathode ray tubes), X-ray machines, and RF amplifiers. Their simple production also makes them dependable and fee-powerful for high-voltage programs. Over the years, several versions of voltage multiplier topologies have emerged to satisfy diverse operational needs. The Villard and Dickson multipliers, as an example, are each



designed with specific blessings and obstacles, from managing different voltage tiers to retaining balance and efficiency. While the Villard circuit is simple however vulnerable to excessive ripple [2], the Dickson price-pump multiplier has located sizable utility in incorporated circuits because of its compatibility with semiconductor fabrication methods and its powerful voltage output in area-restricted designs [4].

Recent advances in semiconductor materials and component technology have made DC voltage multipliers more efficient, robust and reliable. The introduction of silicon carbide (SiC) and gallium nitride (GaN) diodes has improved performance at voltage in higher voltages, while low equivalent series resistance (ESR) capacitors have helped reduce voltage ripples there was a discharge of more stable outputs. Multi-phase voltage multipliers, a recent innovation, use phase-shift inputs to reduce ripple and improve efficiency, which has proven useful in high-frequency applications This development has given DC voltage the use of multipliers is widespread in emerging areas such as energy storage and renewable energy systems. Effective power conversion was important.

Despite these advances, challenges stay in optimizing voltage multipliers for various realistic requirements, together with reducing power loss, handling thermal balance, and keeping efficiency across fluctuating masses. As research continues, new designs and configurations are being advanced to deal with these limitations, ensuring voltage multipliers can meet the demands of cutting-edge digital structures more efficiently. This paper offers an in-depth take a look at the design, simulation, and analysis of DC voltage multipliers, specializing in optimizing efficiency and output balance. Following a comprehensive assessment of present literature on various multiplier topologies and their sensible applications, this looks at information about the design method, from component choice and circuit configuration to calculating the necessary parameters for most excellent performance. By evaluating theoretical predictions with simulated results, this observes objectives to offer insights into the design improvements and improvements required for developing efficient, dependable DC voltage multipliers in modern electronic structures.

2. LITERATURE REVIEW

DC voltage multipliers are essential components of modern electronic devices, applications that require high DC power from low voltage sources, not dependent on transformers or AC power This literature review covers the historical developments, major multiplier topologies, component technology development, DC voltage multiplier and examines its emerging applications. The foundation of the DC-voltage multiplier was laid in the early 20th century with the development of the Cockcroft-Walton (CW) multiplier, invented by physicists John Cockcroft and Ernest Walton to accelerate the particles in 1932. A CW multiplier also known as a "ladder" or "cascade" multiplier It uses phased capacitors and diodes to increase the voltage and this topology has become standard in high-voltage and low-current applications, proving its value in areas such as atomic physics, CRTs, and high-power experimental devices due to its straightforward and scalable design [1].

Subsequent developments brought about versions of the multiplier idea, together with the Villard multiplier, introduced by way of Paul Villard. This unmarried-stage circuit additionally



makes use of a capacitor-diode community to double voltage however lacks the multi-level scalability of the CW circuit, resulting in better ripple and obstacles in its programs. The Greinacher multiplier, which added cascading of Villard circuits, similarly advanced into the CW configuration, laying the groundwork for voltage multiplier designs that would manage better outputs with greater stability and performance [2]. Another widely accepted design is the Dixon charge pump multiplier, developed by Dixon in 1976 for on-chip power supply applications. The Dixon multiplier is notable for its integration in the semiconductor industry, enabling efficient voltage in integrated circuits (ICs) with limited space [4].

Types of Voltage Multipliers and Topological Variations

Many DC voltage multiplier topologies have been developed to suit different needs in terms of output voltage, efficiency, ripple, and compactness. The high-voltage design commonly used in laboratory equipment and older CRT displays, the Cockcroft-Walton multiplier, is well developed for its scalability, making it more efficient in generating DC voltages well above the input source. However, the CW system suffers from large ripple, especially at high voltages, which requires ripple reduction techniques for stable output [1]. Originally designed for silicon-based ICs, the Dixon charge pump multiplier is commonly found in compact portable devices, such as mobile phones and microcontrollers. This is designed to provide a strong DC voltage on chip, high external voltage. Without the need for components, which makes it valuable in power management circuits, the Marx generator, while not a continuous DC multiplier, is distinguished by its pulsed high-voltage generation consumption applications in areas such as radar, laser systems, and medical imaging. Unlike conventional multipliers, the Marx generator executes several steps in succession, producing higher power in a shorter period of time. Although these pulses are not continuous, the principles of the Marx generator have motivated designs of DC multipliers with the high voltages required.

Recent Advancements and Efficiency Improvements

Recent research has focused on improving efficiency, reducing ripples, and increasing thermal stability by improving semiconductor materials and circuit design. The integration of Schottky diodes into CW multipliers revealed that greatly reduces power losses due to their lower forward voltage. The study of Liu et al. (2010) and Timers et al. (2000) and the author. In addition, low-equivalent series resistance (ESR) capacitors have helped reduce voltage ripple and increase stability, which is important for applications that require accurate and robust high-voltage output [6]. The improvement of multi-section voltage multipliers is some other latest advancement aimed toward enhancing overall performance in excessive-frequency packages. Multi-phase designs involve using phase-shifted input indicators across more than one stage, lowering ripple and balancing the weight extra evenly. Research by means of Ye and Lee (2011) indicates that multi-section configurations reap smoother outputs and greater performance, making them appropriate for excessive-frequency programs, consisting of RF amplification, and in gadgets where regular voltage is vital [7].

In addition, material advances in materials such as silicon carbide (SiC) and gallium nitride (GaN) diodes have enabled voltage multipliers to operate at higher voltages and temperatures while maintaining performance. These materials are known as it has higher breakdown voltages



and lower conduction losses, leading to higher frequencies. Voltage multipliers can perform well in high voltage conditions. The study by Bergman and Park (2016) supports that GaN-based diodes provide better performance in high power applications due to their reduced switching losses and better thermal properties [8].

Voltage Multipliers in Modern Applications

Voltage multipliers have come to be an increasing number of essentials in contemporary programs together with energy harvesting, medical devices, and renewable strength structures, wherein compact, high-efficiency electricity conversion is critical. In strength harvesting structures, multipliers are used to enhance low-enter voltages from assets like solar panels and piezoelectric substances to usable stages for digital devices. Studies with the aid of Abeywardena et al. (2016) have proven that Cockcroft-Walton multipliers may be adapted for use in photovoltaic systems to obtain efficient power transfer [9]. Medical programs additionally benefit from improvements in voltage multiplier design. High-voltage, low-ripple multipliers are vital in X-ray generation and different imaging systems in which precision is paramount. Research by means of Omran and Said (2018) highlights that multipliers designed for scientific applications ought to cope with specific demanding situations inclusive of minimizing electromagnetic interference and making sure constant output under various load conditions [10].

In summary, DC voltage multipliers are well-established, adjustable circuits with a wide range of applications. Cockcroft-Walton-Dixon multipliers are still widely used topologies, with much research aimed at enhancing their performance, stability and integration into modern systems. Although considerable progress has been made, there are still challenges in optimizing these circuits for different applications, especially in dynamic environments where inputs are variable and devices are used, e.g. responsive circuits, and the use of advanced materials offer possible avenues for further research. This review builds on the existing literature, and focuses on the design, simulation, and analysis of an optimized DC voltage multiplier. Through simulation, we aim to analyse multiplier performance under different operating conditions, providing insights into how theoretical designs hold practical constraints. Conclusion More efficient stable DC voltage for advanced applications in electronics and power systems.

1.2 WORKING OF VOLTAGE MULTIPLIER:

DC voltage multipliers are circuits designed to increase the voltage from a DC power source by slowly charging and discharging capacitor-diode grids. The basic principle behind voltage multipliers is controlled charge transfer through diodes and capacitors to build voltage at incrementally, well enough to hit the original input voltage. This section describes the operating procedure of DC voltage multipliers, focusing on the main components and the operating steps involved in voltage multiplication. The essential operation of a DC voltage multiplier revolves round controlled rate transfer via diode-capacitor networks, with every level adding to the overall output voltage. Whether the usage of conventional ladder configurations just like the Cockcroft-Walton multiplier or current, incorporated designs just like the Dickson charge-pump multiplier, DC voltage multipliers are integral in eventualities wherein compact and green excessive-voltage DC conversion is needed. Understanding those operating principles

presents the idea for optimizing voltage multiplier designs to satisfy specific software requirements in terms of output stability, efficiency, and issue reliability.

2. DESIGN:

The DC voltage multiplier design includes 4 capacitors, 4 diodes, AC supply given to the circuit for determining the voltage across the C1, C2, C3 & C4.

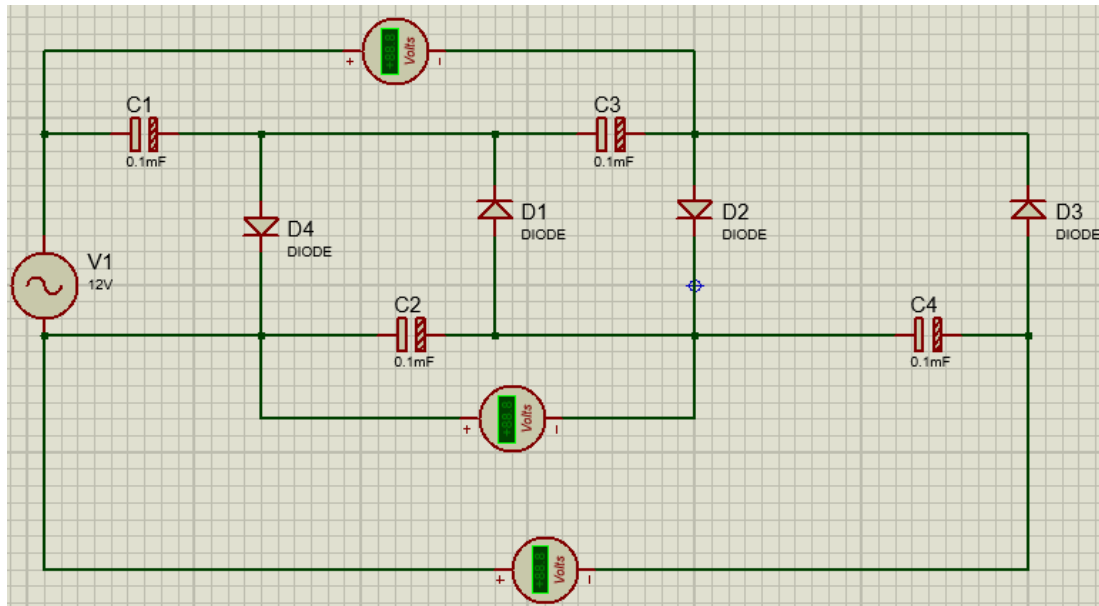


Fig. 1. Circuit diagram for multiplier circuit

SIMULATION:

Proteus software was used to simulate the DC voltage multiplier. All the components are placed perfectly in the Proteus software. Then all components are connected as per requirement. The key components which played a major role in doubling the output voltage are diodes and capacitors.

SIMULATION PARAMETERS:

Sl. No.	Components	Specification
1	Capacitors	0.1 mF
2	Diode	Generic Diode
3	AC Supply	5 V – 12 V
4	DC Voltmeter	-

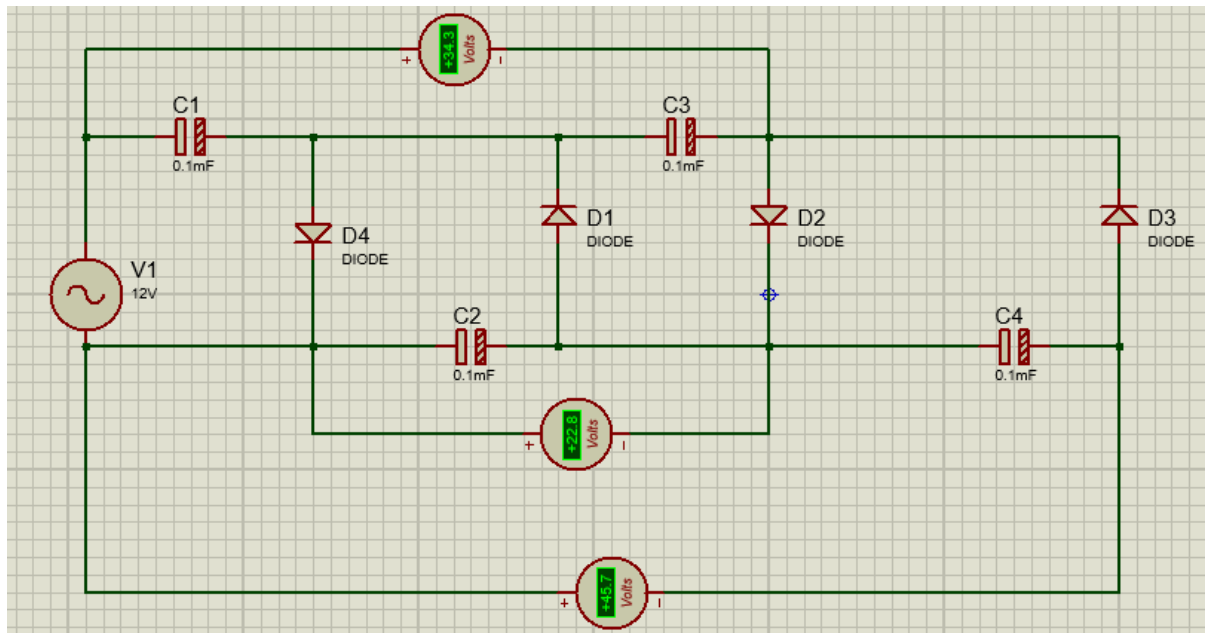


Fig. 2. Circuit diagram and voltage display of multiplier circuit across different capacitor

4. RESULT ANALYSIS:

From figure-1 we observe that the voltage gain is perfectly done, from the given below table we can easily understand how much voltage will be obtained.

$$\text{Voltage gain} = (\text{output voltage}) / (\text{input voltage})$$

Sl. No.	Input voltage (V)	Output (y) voltage (V)					
		y=2x		y=3x		y=4x	
		Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical
1	5	8.9	10	13.4	15	17.8	20
2	6	10.7	12	16.3	18	21.7	24
3	8	14.9	16	22.3	24	29.8	32
4	10	18.8	20	28.3	30	37.7	40
5	12	22.8	24	34.3	36	45.7	48

As per the above table, we considered two variables i.e. X and Y for input voltage and output voltage respectively. Here Y is a dependent variable. We considered it in three different ways i.e. doubler(2x), tripler (3x), quadrupler (4x) for which we get different practical values that are compared with theoretical values. From the above table nearly we get the theoretical voltage gain.



5. CONCLUSIONS:

Voltage Gain						
Sl. No.	Voltage Doubler		Voltage Tripler		Voltage Quadrupler	
	Theoretical gain	Simulation gain	Theoretical gain	Simulation gain	Theoretical gain	Simulation gain
1	2	1.78	3	2.68	4	3.56
2	2	1.78	3	2.71	4	3.61
3	2	1.86	3	2.78	4	3.72
4	2	1.88	3	2.83	4	3.77
5	2	1.9	3	2.85	4	3.80

In the end, DC voltage multipliers are important components for effectively converting low-voltage DC assets into high-voltage outputs in diverse programs. The evaluation of different multiplier topologies, specifically the Cockcroft-Walton and Dickson configurations, highlights their wonderful blessings and challenges. While the CW multiplier excels in voltage gain, it suffers from big ripple, making it less suitable for precision applications. Conversely, the Dickson multiplier offers more stability and performance, especially in compact devices. Recent improvements in aspect technologies, which include low-ESR capacitors and Schottky diodes, have further more desirable performance, paving the way for advanced designs. Future studies need to recognition on optimizing those circuits for dynamic conditions, making sure they meet the evolving demands of present day digital structures.

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