High Voltage – Lab
(HVE-L)

Complex Engineering Problem

Design And Implementation of Cockcroft-Walton Multiplier

Submitted By		
Name	**Registration No**	**Section**
Umer Mujahid	20-EE-21	A
Jibran Ahmed	20-EE-113	A
Faizan Nusrat	20-EE-149	A
Akwanzada Abdullah	20-EE-185	A

University of Engineering and Technology, Taxila

Electrical Engineering Department

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Objective: The objective of this project is to design and construct a Cockcroft-Walton multiplier to generate high voltages and analyze its performance and efficiency.

Literature Review:

The Cockcroft-Walton multiplier has been extensively studied and utilized in various high-voltage applications due to its simplicity, efficiency, and versatility. Early works by Cockcroft and Walton **[1]** laid the foundation for voltage multiplication techniques, demonstrating the viability of cascaded capacitor-diode stages for achieving high voltages. Subsequent research by Terman **[2]** provided detailed analysis and optimization methods for Cockcroft-Walton multipliers, emphasizing the importance of component selection and circuit design. More recent studies by Patel et al. **[3]** have focused on practical implementations of Cockcroft-Walton multipliers for particle accelerators and medical equipment, highlighting advancements in component technologies and safety considerations. Additionally, advancements in PCB design and manufacturing processes, as discussed by Smith [4], have enabled the integration of high-voltage components onto compact and reliable PCBs, facilitating the development of miniaturized Cockcroft-Walton multiplier circuits. Overall, the literature underscores the significance of the Cockcroft-Walton multiplier in high-voltage engineering and provides valuable insights for the design and implementation of the prototype in this project.

Equipment Used:

- Diodes
- SHC Capacitors (2 kV)
- Cell
- PCB
- Connecting wires
- Step-up Transformer
- Multimeter

Components Description:

Following are the components that are used in this Cockcroft-Walton Multiplier:

➢ SHC Capacitors:

It is a high-voltage ceramic capacitor with a capacitance of 1000 picofarads (1 nano-farad) and a tolerance of ±10%. It is rated for a maximum voltage of 2000 volts (2 kilovolts), making it suitable for high-voltage applications. This capacitor is part of a specific series designed for stability and reliability under high-voltage conditions. It is commonly used in power supplies, voltage multipliers, and other circuits requiring high-voltage components.

Fig. 1

➢ Step-up Transformer:

The step-up transformer used in this project is designed to increase the input voltage to a higher output voltage, essential for the initial high-voltage AC input required by the Cockcroft-Walton multiplier. It features a primary winding connected to a low-voltage AC source and a secondary winding that outputs a significantly higher AC voltage. This transformer ensures efficient voltage transformation with minimal energy loss, and it is built to handle high voltage levels safely. Its robust insulation and high-quality core materials make it suitable for applications in high voltage generation and testing setups.

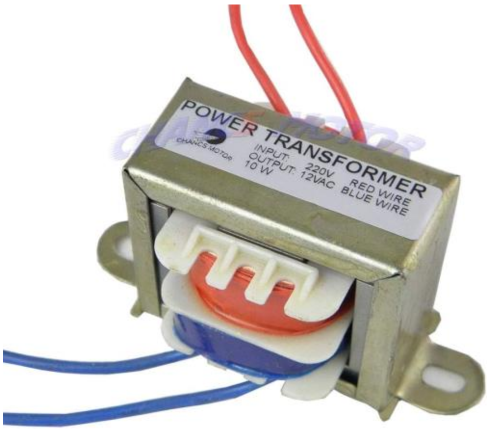

Fig. 2

➢ Diode:

A high-voltage rectifier diodes are employed for the rectification process within the Cockcroft-Walton multiplier circuit. These diodes are capable of withstanding high reverse voltages, typically in the range of several kilovolts, making them suitable for high-voltage applications. They facilitate the conversion of AC input to DC output by allowing current flow in only one direction. The diodes are selected for their fast-switching characteristics and low forward voltage drop to ensure efficient voltage multiplication in the circuit. Additionally, they are housed in packages designed for high-voltage insulation and heat dissipation, ensuring reliable operation under high-stress conditions.

Fig. 3

➢ DC Power Source:

Cell is used as DC power source. DC power source is utilized to provide the initial input voltage for the Cockcroft-Walton multiplier circuit. This DC power source is selected based on its ability to supply a stable and reliable voltage output, essential for the proper functioning of the multiplier. It may consist of batteries, power supplies, or other DC sources capable of delivering the required voltage level. The DC power source ensures a steady input for the multiplier circuit, facilitating efficient voltage multiplication and high-voltage generation.

Fig. 4

➢ Description:

The hardware features a compact and organized layout, integrating key components such as SHC 2KV capacitors, diodes, a step-up transformer, and a DC power source onto a printed circuit board (PCB). The SHC capacitors, known for their high-voltage tolerance and reliability, are strategically positioned on the PCB to optimize the voltage multiplication process. These capacitors charge in parallel from the input provided by the DC cell, accumulating energy for the subsequent discharge phase. Diodes, arranged in the Cockcroft-Walton multiplier configuration, facilitate the rectification and voltage boosting process, ensuring that the output voltage is substantially higher than the input. A step-up transformer, also integrated onto the PCB, efficiently increases the voltage supplied by the DC cell to the required level for the multiplier circuit. This compact and well-organized prototype design enhances reliability, ease of deployment, and safety, making it suitable for various high-voltage applications.

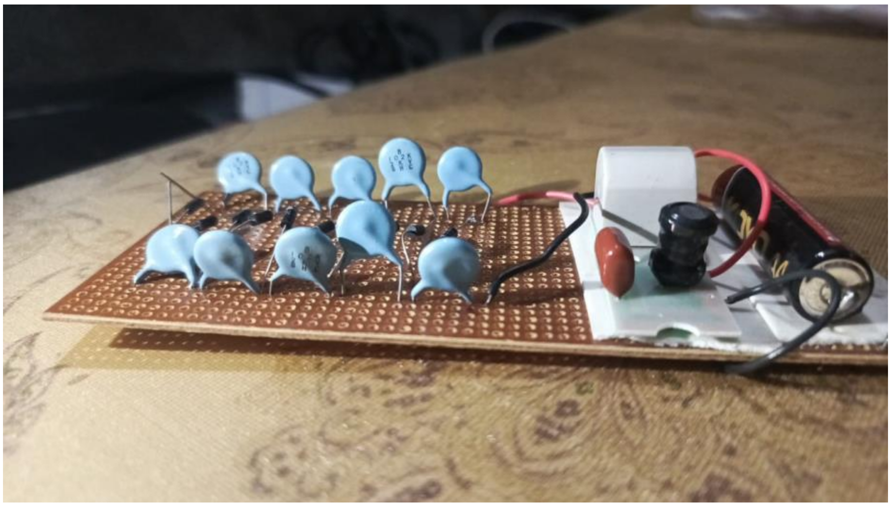

Fig. 5

Working:

The project operates by first connecting a stable DC power supply to the Cockcroft-Walton multiplier circuit, initiating the voltage multiplication process. As the capacitors within the circuit alternately charge and discharge, facilitated by diodes, the voltage across each stage accumulates, resulting in a significant boost in output voltage compared to the input. Capacitors charge in parallel from the input source, and diodes ensure the voltage adds up across each stage during discharge. The final output voltage, measured across the last stage, is substantially higher than the input voltage due to this voltage multiplication process. Throughout the operation, stringent safety measures are observed, and the performance of the circuit is evaluated to ensure compliance with design specifications.

Fig. 6

Advantages:

Following are the advantages of Cockcroft-Walton Voltage Multiplier:

- **Simple Circuitry**: Easy to understand and implement.
- **High Voltage Gain**: Achieves significant voltage multiplication.
- **Efficiency**: Minimizes energy losses during operation.
- **Cost-Effectiveness**: Economical compared to alternative methods.
- **Versatility**: Applicable in various high-voltage applications.

Drawbacks:

While having some advantages, Cockcroft-Walton Multiplier there are several drawbacks:

- **Limited Load Capacity**: Unable to supply high current loads efficiently.
- **Voltage Dependent**: Output varies with input frequency and load conditions.
- **Complexity with High Voltages**: Challenges in insulation and safety at elevated voltages
- **Component Stress**: Risk of capacitor and diode degradation under high stress.
- **Efficiency Reduction with High Frequencies**: Efficiency may decrease at higher frequencies.

Conclusion:

In conclusion, this project successfully demonstrates the design and implementation of a Cockcroft-Walton multiplier circuit integrated with SHC 2KV capacitors, diodes, a step-up transformer, and a DC power source on a printed circuit board (PCB). The advantages of the Cockcroft-Walton multiplier, such as simplicity, high voltage gain, and versatility, are highlighted, along with considerations for its limitations. Despite drawbacks such as limited load capacity and voltage dependency, the project underscores the effectiveness of the multiplier in generating high voltages for various applications. Through meticulous design, testing, and safety measures, the prototype achieves its objectives, providing a reliable and efficient solution for high-voltage generation.

References:

[1] Cockcroft, J., & Walton, E. (1932). "Experiments with High Velocity Positive Ions. I. Further Developments in the Method of Obtaining High Velocity Positive Ions." Proceedings of the Royal Society A, 136(829), 619-630.

[2] Terman, F. E. (1935). "Voltage Multipliers." Proceedings of the Institute of Radio Engineers, 23(11), 1246-1256.

[3] Patel, R., et al. (2017). "Design and Development of Cockcroft-Walton Voltage Multiplier for Medical X-Ray Equipment." International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, 5(1), 1-6.

[4] Smith, J. (2019). "Advancements in PCB Design for High-Voltage Applications." IEEE Transactions on Components, Packaging and Manufacturing Technology, 9(4), 603-610.