THE COCKROFT-WALTON VOLTAGE MULTIPLIER

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This is an interesting voltage multiplier circuit that can be used to generate any high DC voltage at low current drain from a lower voltage AC supply, without using transformers or other complicated circuitry. It was first presented by Cockroft J.D. and Walton E.T.S. in the Proceedings of the Royal Society, London in 1932. However, the circuit appears to have been originally developed as early as 1919 by a Swiss physicist Heinrich Greinacher, but remained unnoticed.

Fig.1 shows the circuit of a N-stage Cockroft-Walton voltage multiplier chain. If the AC input voltage is E_{rms}, this circuit gives, at low currents, a DC output of

$2 \times E_{peak} \times N$ volts, where $E_{peak} = 1.414 \times E_{rms}$.

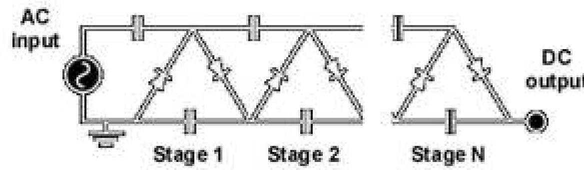

Fig.1. Cockroft-Walton Voltage-multiplier Chain

Though the circuit looks deceptively simple, it is not that easy to explain. Referring to Fig.1, the capacitors on the top leg have a DC voltage across them with superposed AC surging through them. The capacitors on the bottom leg have only the DC voltage of 2 E_{peak} across them.

Fig.2. Cockroft-Walton High-voltage Generator

Any number of stages can be added to the circuit, and each additional stage raises the output voltage by 2 E_{peak}. *The beauty of the circuit is that, irrespective of the number of stages, all the diodes and capacitors used need have a voltage rating of only 2 E_{peak}.* Because of this reason, the Cockroft-Walton voltage multiplier is easy to build, and is used extensively in High-energy Physics, Lightning Research etc.

Fig.2 shows the picture of an impressive very-high-voltage DC generator assembly based on the Cockroft-Walton voltage-multiplier chain that is on display in the Science Museum, London. It was used in the research that led to the development of the atom bomb.

Most of us get no opportunity to work on high-voltage generators, so let us at least have some fun assembling a minimal version of such a generator. Fig.3 shows the circuit of a simple 2-stage Cockroft-Walton voltage-multiplier DC supply that employs just four 1000 PIV silicon rectifiers and four 1 μF paper capacitors rated at 250VAC/ 600VDC. The neutral line of the 230-volt mains supply is the base-line for the voltage multiplier. Every power supply providing a DC output must have a closed DC path and, in Fig.3, it is 'abcdea'.

Fig.4 shows the unit assembled in breadboard fashion on a 6”x4” epoxy board. With an input voltage of 230VAC, this circuit gives an output of 1240VDC. To measure the output voltage at A, measure the voltages between N & O and O & A (using a 20,000 ohms/volt multimeter in the 1000VDC range), and add up. The 20-megohm load on the output (two 10-megohm 1-watt resistors in series) discharges the capacitors after the unit is switched off. High-value 0.5-watt resistors have a tendency to change their resistance even with moderate heating up, so 1-watt resistors are used.

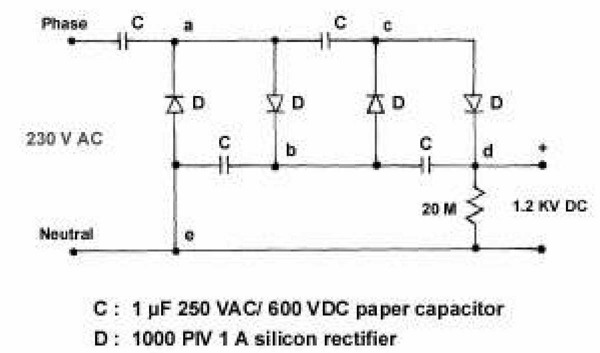

Fig.3. Cockroft-Walton 2-stage Voltage-multiplier Circuit

This little gadget would be very useful in an experimenter’s shack for testing 1000PIV silicon rectifiers and 1KV mica or ceramic capacitors (especially the military-disposal capacitors commonly used by amateur experimenters). For such tests, connect one end of the capacitor or the cathode of the rectifier to A (using the screws on the ceramic-mounted terminal). With the multimeter in the 1000VDC range, connect its black lead to the terminal at N. Then turn on the Voltage multiplier and touch the free end of the device with the red lead of the multimeter. A steady reading close to zero indicates that the device is good.

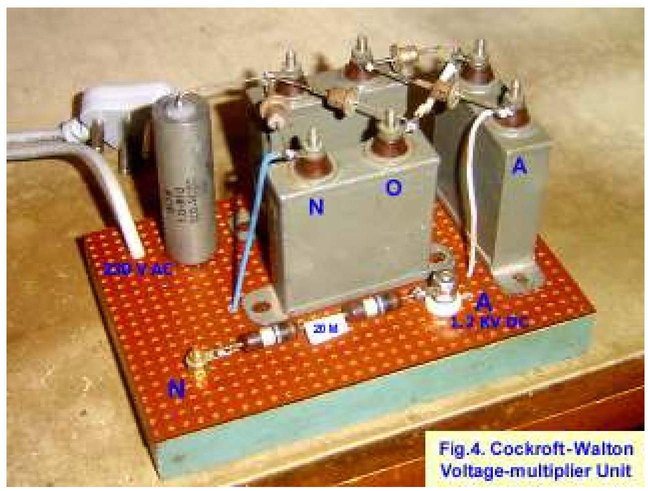

Fig.4. Cockroft-Walton Voltage-multiplier Unit

It goes without saying that the builder should assemble and handle a high-voltage gadget like this with due caution. The phase and neutral lines of the circuit should be correctly wired to a 3-pin mains plug.

Reference – Wikipedia: Cockroft–Walton generator.

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