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Development of 8-stage gas discharge tube-based compact Marx generator as high voltage pulse generator

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1. Introduction

This paper describes a compact 8-stage Marx generator using gas discharge tubes (GDT) as a fast-rise, high-voltage pulse generator. It uses GDT as a spark gap switch, ensuring long, reliable operation and a fast rise time of 54 ns.

Marx generator is generally used to generate fast rise, high-voltage impulse [1,2]. The charging capacitors at each stage are parallelly charged and discharged in series. Switches that can simultaneously close are needed to be discharged in series. Solid-state Marx generators have recently been commonly used due to the advances in power semiconductors, but using a spark gap is still a valid option as a Marx generator switch [3]. A Spark gap is advantageous since other spark gaps are automatically ignited when the first spark gap ignites. [4] This is possible as all the spark gaps hold voltage close to the self-ignition. Therefore, external synchronization of all switches is unnecessary, and only the first switch should be triggered. This work uses commercial GDT (gas discharge tube) as a spark gap switch instead of a crafted spark gap switch. It is built as a surge suppressor, so it ensures reliable operation and guarantees accurate self-breakdown voltage values [5,6]. GDTs are inexpensive and small, making them ideal for compact Marx generator switches.

2. Methods and Results

2.1 GDT-based Marx generator

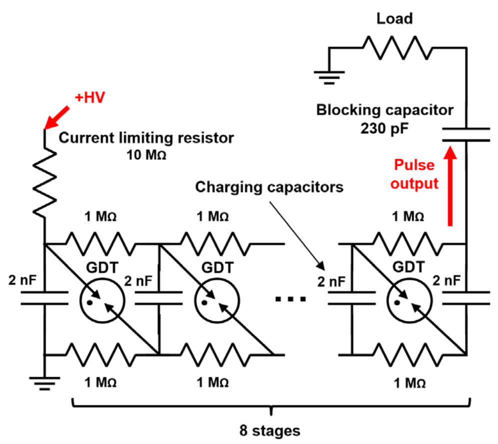


Fig 1. Schematics of 8-stage GDT-based Marx generator

In this experiment, the Marx generator is triggered by over-voltage, also called self-breakdown. Positive high voltage higher than the self-breakdown voltage of GDT continuously charges charging capacitors through a current limiting resistor, and the voltage applied to the GDTs increases. As the largest voltage is applied to the GDT of the first stage while charging, it reaches its self-breakdown first, and discharge occurs. Overvoltage is applied to the GDT of the next stage instantaneously, and discharges occur successively. This process is instantaneous for the GDTs of all the stages, resulting in the same as if all the capacitors were connected in series and the generation of a high voltage pulse.

2.2 Gas discharge tube (GDT)

The CG37.5L at Littlefuse Inc. is used as GDT for this Marx generator. Its DC breakdown voltage is 7.5 kV, ensuring a minimum DC breakdown voltage of 6.0 kV. In experiments, the Marx generator did not self-trigger for an hour with a charging voltage of 7.0 kV but became unstable at a higher voltage. Therefore, self-breakdown occurs at least when the charged voltage exceeds 7.0 kV. As GDT is compact, completely sealed, and inexpensive, the number of stages of the Marx generator can be easily extended.

2.3 Output voltage for various impedance loads

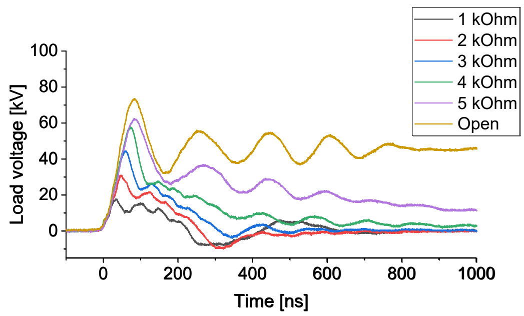


Fig 2. Marx generator output voltage for various loads.

The Marx generator is tested for various impedance loads. A thick film non-inductive resistor is used as a load. In Figure 2, self-breakdown-triggered Marx generator output is applied to multiple loads. The rise start time is set as t = 0 ns. The maximum output voltage for an open load is 72 kV, and a rise time from 10 % to 90% is 54 ns, showing a rise of about 1.1 kV/ns.

A load voltage is almost proportional to the load impedance. This implies that the Marx generator's impedance is far larger than a few kiloohms. The exact evaluation of generator impedance is not conducted as there are non-resistive impedance values due to stray capacitance of circuit elements. As the output pulse rise is very fast, the current conducted by stray capacitance is dominant, although a non-inductive resistor is used as load.

2.4 Trigatron turn-on experiment

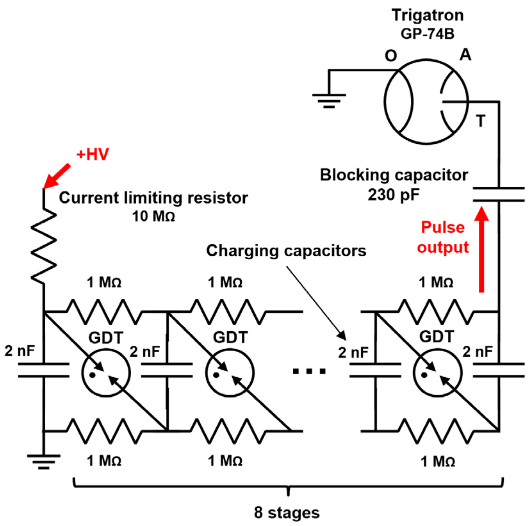
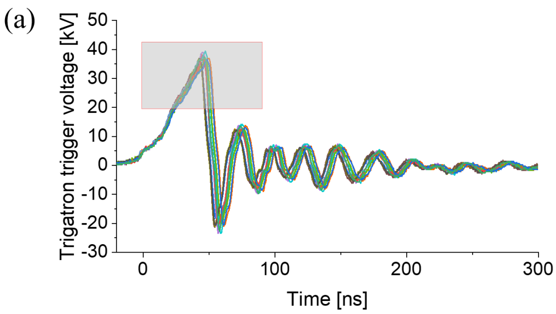


Fig 3. Schematics of trigatron turn-on experiment.

Trigatron is the most used switch device for high-voltage, large-current switching, which is important for pulsed power experiments. When the trigatron is triggered, a spark generated between the T (trigger) electrode and the A (adjacent) electrode connects all electrodes inside the trigatron, making them almost the same voltage. Trigatron triggering needs a high voltage of roughly 15 kV or higher as the spark between the A-T electrode should be made. [7] Therefore, this Marx generator is ideal for triggering trigatron. GP-74B trigatron of Excelitas Tech. Corp. is used in turn-on experiments.



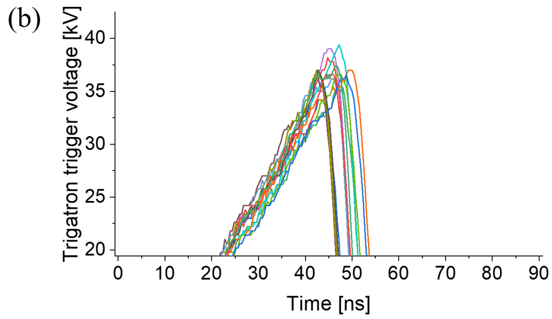


Fig 4. (a) Trigatron T (trigger) electrode voltage. (b) The zoomed graph when the trigatron turned on.

The Marx generator output voltage is applied to the trigatron trigger electrode through a blocking capacitor. In Figure 4, the trigger voltage drops to zero at a specific time. This is when the spark connects the T-A-O electrode inside the trigatron, so a trigger electrode's voltage becomes zero as the O electrode connects to the ground. This experiment's critical parameters are turn-on delay and turn-on time jitter. If both values are known, trigatron control to be turned on desired time is possible. When the time rise starts is t = 0 ns, the turn-on delay is 46.1 ns, and the turn-on time jitter is 2.3 ns. This time jitter is small enough for synchronization with laser devices or other pulsed power devices and presents the possibility of being applied to pulsed power experiments.

3. Conclusions

An 8-stage GDT-based compact Marx generator is developed. By adoption of GDT, reliable operation is possible. Marx generator produces high voltage, fast rise pulse with 72 kV maximum voltage, and 54 ns rise time. Its trigatron turn-on delay is 46.1 ns, and its turn-on time jitter is 2.3 ns, good enough to synchronize with other pulsed power devices.

Acknowledgments

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