An 8kV Series-Connected MOSFETs Module that Requires One Single Gate Driver

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INTRODUCTION

Repetitive frequency nanosecond pulse technology has extensive application prospects in many fields such as material processing, chemical synthesis, biomedicine, disinfection and sterilization, and environmental protection. Nowadays, higher requirements have been put forward for nanosecond pulse generators in miniaturization, stability, and waveform controllability.

This paper has designed a new series-connected MOSFETs structure which only requires one single external gate driver to control it. The pulse generator using only one MOSFETs module can generate a square pulse that has 10kHz repetitive frequency, 8kV voltage magnitude and 15ns rise time.

OPERATING PRINCIPLE

1. Off state: The driver output maintains a negative level and all the MOSFETs are in the off state. And the gate trigger capacitors C_2 to C_{10} are charged to source potentials of M_2 to M_{10} through Corresponding bleeder resistors R_{12} to R_{20}.
2. Turn on process: The drive output rises from negative level to positive level. M_1 is first turned on, its drain-source voltage drops rapidly. That is, the source potential of M_2 drops rapidly. The opening process of M_1 will cause the trigger capacitor C_2 to perform a quick charge on the gate capacitance C_{GS2} of M_2. When the voltage of C_{GS2} reaches the opening threshold of M_2, M_2 will also turn on. Similarly, the turn-on of M_1 and M_2 will cause the trigger capacitor C_3 to charge the gate capacitor C_{GS3} of M_3, and so on. Finally, all the MOSFETs will enter the open process.
3. On-state: The driver output maintains a positive level and all MOSFETs are on. The the series module quickly connects the main capacitor and the load in parallel. This results in a pulsed voltage waveform on the load.
4. Turn off process: The drive output goes from a positive level to a negative level, M_1 starts to turn off, and its drain-source voltage starts to rise. The gate capacitance C_{GS2} of M_2 starts to charge the trigger capacitor C_2. The voltage on C_{GS2} continues to decrease, and after its voltage is less than the threshold voltage of M_2, M_2 begins to enter the turn off process. Similarly, M_3 to M_{10} will also enter the turn off process, the voltage transferred from the load to the series-connected MOSFETs, and a work cycle is completed.

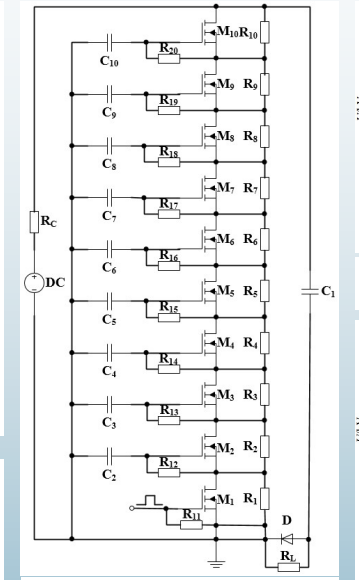


Fig. 1. The circuit structure of the pulse generator.

OUTPUT VOLTAGE

The output voltage of the pulse generator is shown in Figure 2. The leading edge time of 7kV output is 25ns, and the leading edge is not oscillating. But the leading edge time of 8kV and 9kV output is 35ns, and the leading edges are oscillating.

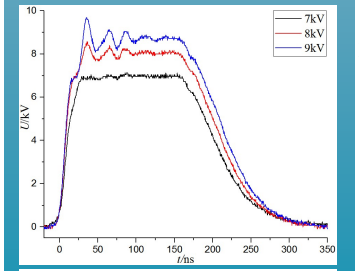
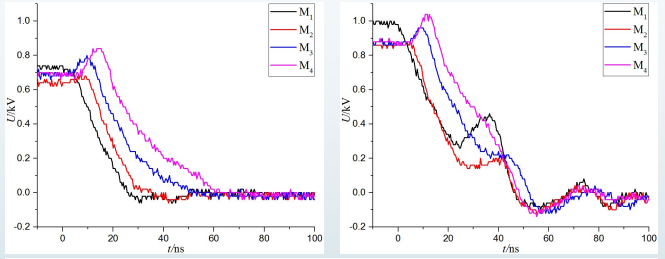
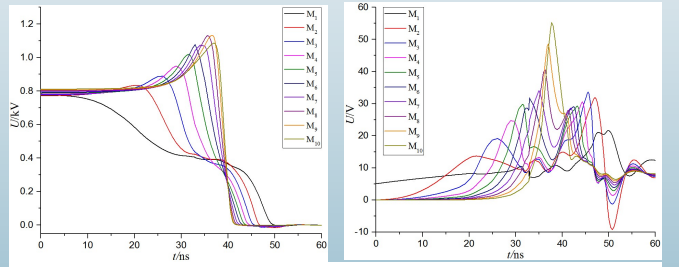


Fig. 2. The output voltage of the pulse generator.



(a) Output voltage 7kV (b) Output voltage 9kV

Fig. 3. The U_{DS} of the first four MOSFETs.



(a) Leading edge of U_{DS} (b) Leading edge of U_{GS}

Fig. 4. The simulation result.

EXPERIMENT AND SIMULATION

The U_{DS} of the first four MOSFETs was measured by using a differential probe. The U_{DS} of the first four MOSFETs is shown in Figure 3. The 7kV is regular and the 9kV is chaotic.

The simulation result is shown in Figure 4. From the simulation results, it can be seen that from M_1 to M_{10}, the sequence is in turn in order of progression. This is consistent with the previous theoretical analysis, but the order of completion of the opening is exactly the opposite. That is, the higher stage MOSFET has the faster opening speed. It can be seen from the gate waveform that the gates of M_2~M_{10} are overvoltage triggered waveforms, with the M_{10} gate voltage peaking at about 55V. It is this overvoltage trigger waveform that results in faster gate charging speeds for higher stage MOSFETs, resulting in turn-on synchronization issues in previous experiments.

CONCLUSION

A new Series-Connected MOSFETs structure was proposed which requires only one single gate driver. The work reliability of the series module was verified through experiments. The reason of the waveform oscillation was explained through simulation. The next research will focus in using an overvoltage driver to trigger the first MOSFET to improve the synchronization of the series module.