High-voltage and High-stability Nanosecond Pulser Based on Avalanche Transistors

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***Abstract*—Based on the avalanche effect, a large amplitude nanosecond pulse generator has been designed, by using the series-transistor Marx circuit. The peak voltage of the output pulse can reach up to 1000V in 50Ω load with 5ns pulse width, 1.2ns rising time and 50kHz repetitive frequency. For higher pulse amplitude, the method of power-combining is used, which needs the pulse-generator-units having high stability of time base. Based on the analysis of the reason why the trigger pulse affects the pulse-generator on the basis of avalanche transistors, we designed an experiment to study the influence rules of the trigger pulse on the stability of the pulse-generator. The experimental results show that we can effectively decrease the jitter of the pulse generator between units by increasing the slope of the trigger pulse. And we make the time-base jitter of the output pulse about 30ps, by using trigger pulse with 5V amplitude and 5ns rising time.**

Keywords—avalanche transistors;Marx circuit;high voltage; time-base jitter;nanosecond pulser.

I. INTRODUCTION

Based on the avalanche effect of avalanche transistors, high-frequency pulses with nanoseconds or sub-nanoseconds rising time and falling time can be generated, which is widely used in Ground-penetrating radar system, driving high speed camera, producing non-thermal plasma and so on. In this article, a nanosecond pulser consists of five strings of avalanche transistors which are connected in the Marx bank configuration is designed. And 1kV peak voltage, 5ns pulse width and 50kHz repetitive frequency pulse has been generated. The influence rules of the trigger pulse on the stability of the time-base jitter of the pulser has also been studied based on the circuit, which can guide us to choose the appropriate trigger pulse according to the requirement of the time-base jitter.

II. HIGH VOLTSGE CIUCUIT DESIGN

To generate high voltage pulse based on avalanche transistors, series-transistor circuit, Marx circuit and series-transistor Marx circuit can be used generally. The series-transistor Marx circuit is chosen, it needs lower DC bias power supply, which make the circuit safer relative to the series-transistor circuit. Compared with the Marx circuit, lower distributed capacitance decreases the rising time and increases the stability of the output pulse.

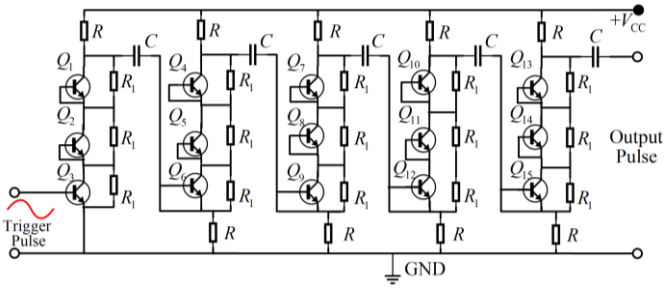

Fig.1 series-transistor Marx circuit

The circuit consists of five strings of avalanche transistors which are connected in the Marx bank configuration, as shown in Fig.1. Each string has three avalanche transistors. The transistors model of Q1-Q15 in the circuit are Fmmt417, whose Vcbo is about 200V and Vceo is about 100V. The charging resistance R is 20kΩ. The equal resistance R1 is 1MΩ, which can prevent damaging the circuit caused by uneven voltage between transistors. In general, we choose the capacitor with larger value, which can increase the amplitude of the output pulse, but also increasing the falling time. To decrease the pulse width, we need to connect a capacitor at the output port. But it can introduce a reflected wave with high voltage, which can easily damage the circuit. In this article, we choose the capacitor with small value (about 150pF) to make the output pulse have a few nanosecond pulse width. And the small capacitance can also decrease the jitter of the waves [2]. The experimental results show that the jitter of the peak voltage and the pulse width is lower than 1%. The output pulse are as shown in Fig.2.

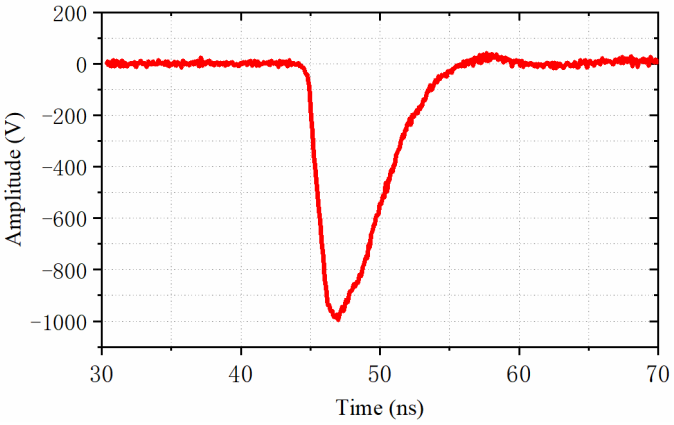

Fig.2 The output pulse of the circuit

As shown in Fig.2, the peak voltage of the output pulse can reach up to 1000V in 50Ω load, the pulse width is about 5ns.The rising time is about 1.2ns. And the repetitive frequency can reach up to 50kHz.

III. EFFECT OF THE TRIGGER PULSE ON THE OUTPUT PULSE

The peak voltage of the pulser output pulse based on the avalanche transistors is usually a few hundred or thousand volts. To generate higher amplitude, power-combining technology can be used, which require high stability pulse-generator-units with small time-base jitter. Therefore, the research on the time-base jitter of pulser is of significant importance.

In the reference [2], the author has theoretically studied the influence rules of the trigger pulse on the stability of the pulse-generator. The paper show that the most important factor is the slope of the rising edge. And the reference [3] shows the experimental results. But the trigger pulse used in the experiment has at least 350V peak voltage with nanoseconds rising time. The experiment with several volts trigger pulse which is usually used to trigger the circuit with small trigger-pulser volume that can integrate into the pulser has not been done. Moreover, they do not give the requirement of the trigger pulse amplitude. Therefore the influence of the trigger-pulse amplitude and the slope of the rising edge with several volts amplitude and a few nanosecond rising time have been studied, by the experiment.

In the experiment, two pulser are triggered with the trigger pulse at the same time and the time-base jitter of the output pulse is estimated by the delay between the two channels. The specific experimental results are shown below.

A. The influence of the trigger-pulse amplitude

We hold the slope of the rising edge about 0.2V/ns, and change the amplitude of the trigger pulse. The total jitter at each amplitude is estimated by the mean value of 300 times trigger result.

If the amplitude of the trigger pulse is lower than 2V, the pulser can't be always normal triggered. In this condition, we can't guarantee that each trigger has an output waveform. The time-base channels jitter of the wavef2orm is very large, which is longer than 10ns.

If the amplitude of the trigger pulse is higher than 2V, the pulser can be triggered normally at each time. The results are as shown in Fig.3 。

It is easy to see that under the condition of the same slope of the rising edge, the time-base jitter of the output pulse has no obvious change with the increasing of the trigger-pulse amplitude, as shown in Fig.3.

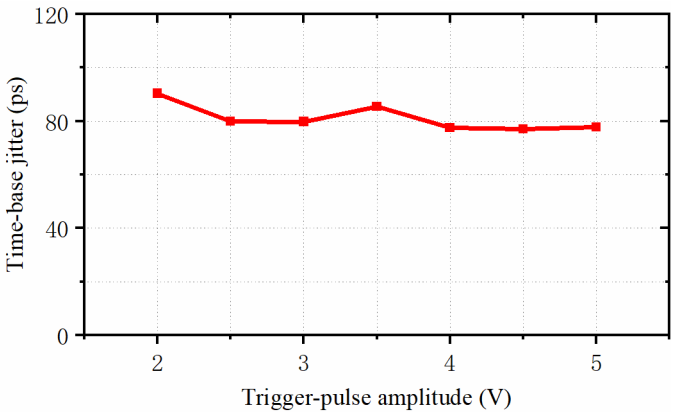

Fig.3 The influence of trigger pulse amplitude on time base jitter

B. The influence of the slope of the trigger-pulse rising edge.

In the experiment, we hold the amplitude of the trigger pulse about 5V, and change the slope of the rising edge by changing the rising time. At each slope of rising edge, 300 times experiment are also conducted to get the mean jitter. The results are as shown in Fig.4.

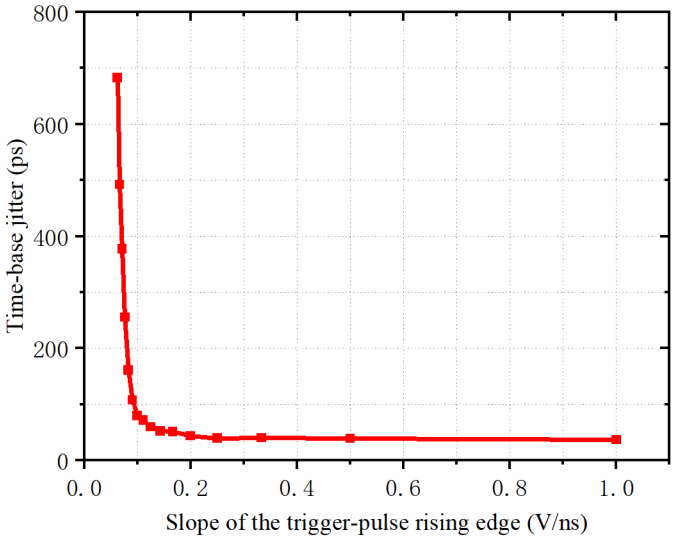

Fig.4 The influence of the slope of the trigger-pulse on time base jitter

The figure shows that with the increasing of the slope of the rising edge, the time-base jitter of the output pulse become smaller and trends stable. If the slope of the trigger-pulse rising edge is lower than 0.1V/ns, the time-base jitter of the output pulse is longer than 100ps, and the time-base jitter decreases significantly with the increasing of the slope of the trigger-pulse rising edge. If the slope of the trigger-pulse rising edge is larger than 0.1V/ns, the time-base jitter of the output pulse is lower than 100ps, and the time-base jitter decreases slowly with the increasing of the slope of the trigger-pulse rising edge.

IV. CONCLUSION

In this article, A pulser is designed based on series-transistor Marx circuit which 1000V peak voltage, 1.2ns rising time, 5ns pulse width, and 50kHz repetitive frequency, and lower than 1% jitter of the peak voltage and the pulse width.

The influence of the trigger pulse on the time-base jitter of the output pulse has also been studied. The results show that the amplitude of the trigger pulse have no obvious effect on the time-base jitter of the output pulse if the amplitude is larger than 2V and the most important factor is the slope of the trigger-pulse rising edge. So we can generalize the influence of the slope of the trigger-pulse rising edge on the time-base jitter of the output pulse to the other trigger-pulse amplitude, Which can guide us to select the trigger pulse as needed. In the end, by using trigger pulse with 5V amplitude and 5ns rising time, we make the time-base jitter of the output pulse about 30ps, which can be well used in power combining.

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