DESIGN AND IMPLEMENTATION OF THE HIGH PERFORMANCE THYRATRON TUBE DRIVER

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Abstract

The precise trigger timing and the output waveform of the thyratron tube are required to achieve optimal working condition of the kicker system in the booster ring. To meet this requirement, a reliable and precise Thyratron driver is needed to trigger the thyratron tube such that the kicker's output performance can meet required specification. In this paper, design and performance of a new Thyratron tube driver deployed in SRRC is described. This driver is capable of delivering Thyratron trigger-pulse with excellent jitter performance, which is smaller than +/-1nS, and the power transfer ratio is efficient. The voltages used to bias Thyratron tube are also included in the design of this driver. It has been tested and proven to be working well in delivering the kicker pulse with excellent stability and reliability.

1. INTRODUCTION

The thyratron tube is a switching device that can endure very high voltage and very high current operation. It is applied in the injection and extraction kicker of the booster ring of SRRC. To ensure the working efficiency of the beam current in the booster ring, the stability of the kicker's output current waveform and the jitter performance are rather important, and relatively, the operation of the thyratron tube must be triggered stably. The quality of the thyratron tube has magnificent effect upon the switching characteristic and lifetime. Three major factors to evaluate the performance of thyratron tube driver are summaried as follows: [1] the trigger jitter [2] the trigger energy [3] the trigger rise time. For the design of the thyratron tube driver SRRC-2500, the above requirements are met. Most special of all, the thyratron tube driver won't be damaged when a system error or an overtime working state happens. The SRRC-2500 thyratron tube driver is more robust than other products in our daily operation.

2. DESIGN PRINCIPLE

The characteristic of the thyratron tube driver is mainly designed to produce a pulse energy signal which meets the threshold voltage or current of the thyratron tube during a specific operating time and to ensure the thyratron tube be triggered fast. In order to achieve the goals, two stages in the system are designed separately. The first stage circuit of the Thyration tube driver is responsible for generating a high-precision low jitter trigger pulse. The second stage is consisted mainly of high-speed transformer, which transfers the trigger pulse from the first stage to trigger the Thyration tube with adequate power transform ration and speed requirement.

In the first stage circuit design, the key is to select a power MOSFET with high-speed characteristic. Power MOSFET drivers is certainly another important factor. When all the parameters are careful designed to be in an optimization state, the first stage output characteristic of the thyratron tube driver meets the specification well. The power MOSFET must have high perk current and high speed to fire power MOSFET parameters. The rise time of the trigger output pulse is less than 30ns. Moreover, the jitter is less than ±1ns. The main circuit diagram of the thyratron tube driver is shown in Figure 1. J2 is the output point of first stage in thyratron tube driver.

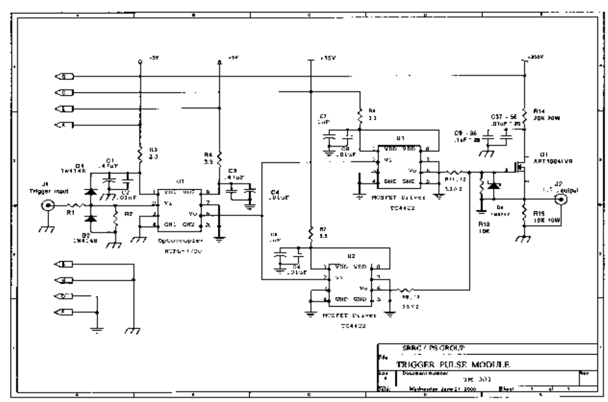

Figure 1: Main circuit diagram of the first stage thyratron tube driver.

Considering the trigger rise time and the trigger jitter in the design, the isolation of the trigger input and output signals is also considered to make sure that the system operates correctly. High-speed opto-isolator is applied to meet the isolation requirement. For the input signal is of the TTL level, two sets of the isolated power system and grounding are needed to supply the circuit normal operation.

Owing to the high-speed pulse is generated from the thyratron tube driver output, the parasitic inductance and capacitance are very sensitively in the circuit. It might result in oscillation of the resonacs. A RDC snubber circuitry across the power MOSFET is adopted to overcome this issue.

For the second stage of the design, a TDK-H1D ferrite core material is selected for the high-speed transformer. The μ value of the high speed transformer is 12500 gauss. The total trigger energy can be transferred in a high speed so thus the thyratron tube can be triggered as soon as possible. The other requirement to trigger the thyratron tube is to set the trigger voltage level larger than 2400V. A turn ratio of 1:4 of transformer is designed to enable the thyratron tube driver meet the requirement. The block diagram is shown in Figure 2.

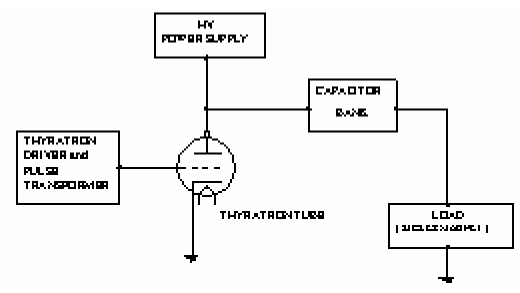

Figure 2. The block diagram of thyratron tube and thyratron driver system.

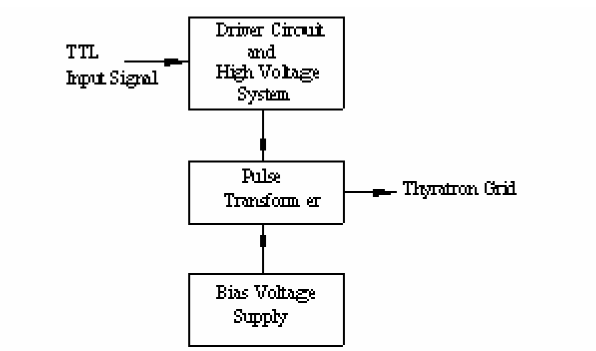

Figure 3. The block diagram of the SRRC-2500 thyratron driver system.

The thyratron driver system block diagram of the SRRC-2500 is shown in Figure 3. The interior important devices can be separated into three parts. First one is the first stage circuit, second is the trigger high-speed transformer, and the last one is the thyratron negative bias system. All the characteristic of these three parts will influence the switching characteristic and the lifetime of the thyratron tube. The photo of the first stage circuit board, which generates 350V trigger pulse output is show in figure 4. The photo of the high speed transformer is shown in figure 5.

3. TESTING RESULT

After finishing the overall circuit design, the SRRC-2500 prototype was built and installed into the booster ring's kicker system to measure its output performance. The first stage trigger output waveform at J2 is shown in figure 6 and zoom-in portion of rising pulse is illustrated in figure 7, to demonstrate the rise time of the trigger output. It can be calculated from figure 5 that the rise time is

$$\text{Calculated Rise Time} = \frac{280V}{23ns}$$

$$= 12.17\text{V/ns}$$

Figure 4: SRRC-2500 thyratron driver first stage circuit board

Figure 5: The pulse transformer of the SRRC-2500 thyratron driver

The trigger speed of the thyratron driver is quite reasonable and good after the testing and verification. Major parameters of SRRC-2500 are listed below:

1. Optocoupler Delay Time: 50ns
2. Driver Delay Time: 35ns
3. Total Delay Time: 130ns
4. High Voltage Rise Time: 84ns
5. Jitter: ±0.2ns
6. Driver Peak Current: 18.16Amp.
7. Pulse Transformer: TDKH1DT60-20-36
8. μ Parameter: 12500 Gauss
9. Pulse Transformer Line: RG-213
10. Turn ratio: 1:4
11. Bias Voltage: -150VDC

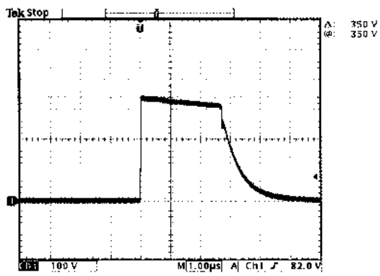

Figure 6: J2 Output Voltage Waveform (On Line Loading).

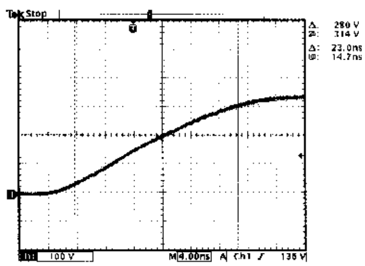

Figure 7: J2 Output Voltage Rise Time: 23ns (On Line Loading).

The rise time and slew rate of the output waveform from the SRRC-2500 driver to the Thyratron Grid 2 Gate, which is the waveform output from the high speed transformer, is shown in Figure 8. It illustrates the jitter performance of SRRC-2500 trigger output pulse.

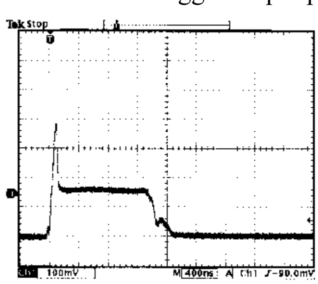

Figure 8: Thyratron Grid 2 Input Voltage Waveform SRRC-2500 (Scale: 1V=1000V).

The measured jitter is about +/-0.2nS, which is far less than the specification of +/-1nS and the jitter performance of the SRRC2500 is demonstrated in Figure 9.

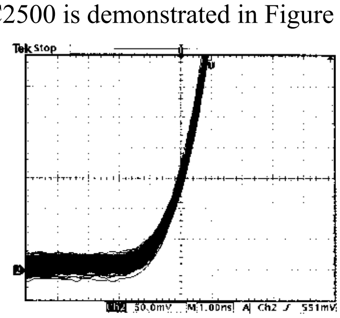

Figure 9: The jitter of the Output waveform, Rg = 1.67 ohm Jitter: ±0.2ns.

We implement the main circuit diagram of the thyratron tube driver is shown in Figure 8. Where is the figure 8 It is the first stage output point of the thyratron tube driver.

The SRRC-2500 Internal arrangement and the assembly of the final driver system are illustrated in Figure 10.

Figure 10: Internal arrangement of SRRC-2500 system.

4. CONCLUSION

In this paper, a rigid thyratron driver capable of delivering thyratron trigger-pulse with excellent jitter performance, which is less than +/-1nS, and efficient power transfer ratio is demonstrated. The voltages used to bias the thyratron tube are also included in the design of this driver. It has been tested and proven to be working well in delivering the kicker pulse with excellent stability and reliability.

5. REFERENCE

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