Transmission Line Pulse Testing and Analysis of Its Influencing Factors

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Abstract. Transmission line pulse (TLP) is a useful tool in immunity test of electrostatic discharge (ESD). The pulse width and rising time of TLP waveform is the key point of the anti-static interference test. A TLP generator is built based on the principle of TLP. The generator is used to test and analyze influences of pulse generating line, relay, pulse transmission line, load and the ground wire of the oscilloscope probe, respectively.

Introduction

Electrostatic discharge (ESD) is an event that limited charge transfer from one object to another. In the process, the strong radiation field and the large current will have an effect on electronic devices through conduction coupling and radiation coupling. Therefore, it is necessary to improve the anti-static interference of electronic equipment. However, in actual test, there are some problems [1, 2] when using IEC61000-4-2 standard to guide the design and testing of electronic devices against ESD, the method of transmission line pulse (TLP) has been applied [3].

In order to analyze the factors that affect the production of TLP, according to the principle of TLP, a TLP generator is built to analyze the influence of different factors on TLP.

TLP Generator

The actual test generator is built on the principle of TLP, and it includes high voltage power supply, coaxial cable, relay, pulse transmission line and load resistor. The principle of TLP is when the switch is closed; the charged coaxial cable discharges to the load and a square wave will be obtained. As shown in Fig. 1, the length of lossless transmission line AB is l, the characteristic impedance and voltage of which is Z_0 and U_0. The voltage U_0 can be divided into the forward wave U_f and the traveling wave U_b. When the time t=0, the switch K is closed and then the coaxial cable will discharge through resistance R. And when the load resistor R equals to the impedance Z_0, the ideal TLP wave can be gotten as shown in Fig. 2.

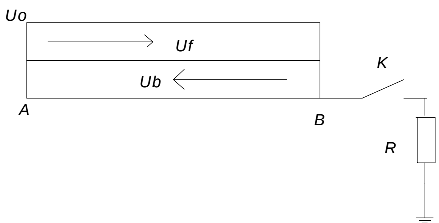

Fig. 1. The principle of TLP

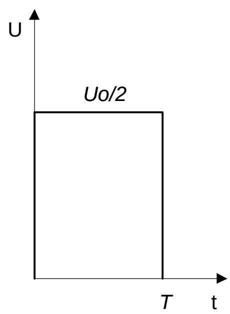

Fig. 2. An ideal TLP waveform

Testing and Analysis of Factors Influencing on Waveform of TLP

The actual TLP structures including high voltage power supply, coaxial cable, relay, pulse transmission line and load resistor. The high voltage power supply is obtained by the multiple voltage rectifier circuit. The output voltage amplitude of multiple voltage rectifier circuit is stable and it has small ripple. It has no other effect on TLP but the magnitude. Therefore, when analyzing

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the influence factors of TLP, the power supply section is not taken into account. Thus the main factors affecting the TLP includes pulse generating line L_1, relay, pulse transmission line L_2, load resistor and the oscilloscope probe ground wire. The following will analyze the impact of these five sections on TLP respectively. In the actual test, the DC power supply voltage is 5V, so the amplitude of the theoretical value of TLP is 2.5V.

The influence of the pulse generating line. Fig. 3 is the TLP generated by a coaxial cable with the length of 11.81m and characteristic impedance of 56.95Ω. Its rise time is 1ns and the pulse width is 118.97ns. The used relay is an un-shielded dry reed relay, and then the relay picks up a 50Ω resistor with short leads. The oscilloscope probe ground wire is short. According to the principle of the TLP generation, after charging the L_1, when the switch is closed, a square wave can be obtained at the load. At this time, the generator without pulse transmission line L_2 can generate a TLP waveform.

To understand the effects of L_1, the coaxial cable with the length of 9.87m and the characteristic impedance of 59.02Ω is selected for testing. The rest test conditions are the same with that of Fig. 3. The resulting TLP is shown in Fig. 4. The rise time is 1ns and the pulse width is 91.38ns.

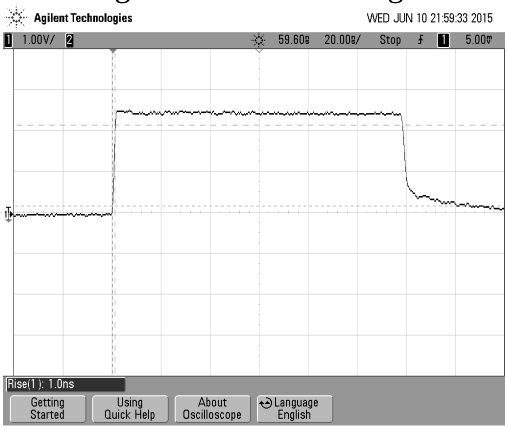

Fig. 3. TLP generated by L_1 with the length of 11.81m

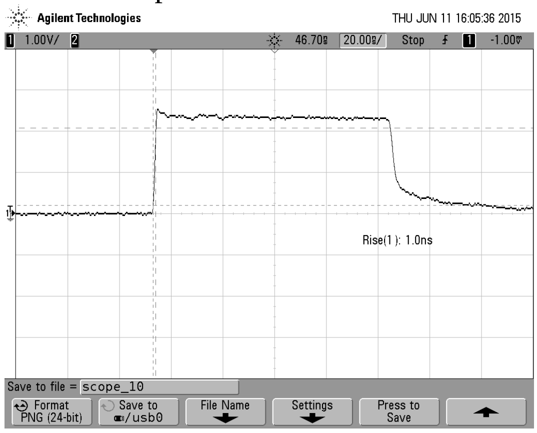

Fig. 4. TLP generated by L_1 with the length of 9.87m

In the following test, the 9.87m coaxial cable is used to test other influencing factors on TLP.

The influence of the relay. It's found that shielding of the relay will also affect waveform of TLP, besides the switching speed, sensitivity, and contact bounce of relay [4]. In the actual test, in order to compare the differences caused by different relay as well as the influence of the shielding of the relay on the TLP, the mercury relay and dry reed relay are chosen for testing and the aluminium foil is used to wrap the relay tightly to analyze the impact of relay shield or not. Details are as follows.

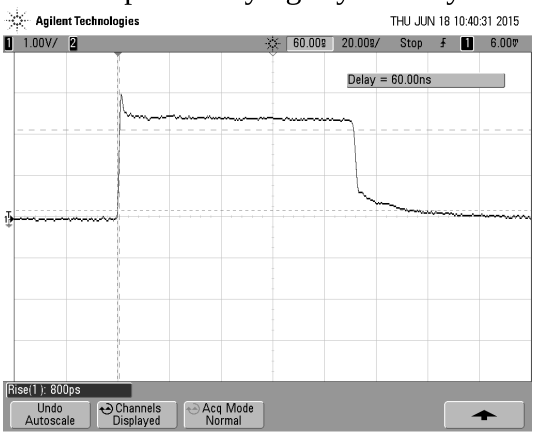

Fig. 5. Waveform of TLP with shielding of dry reed realy

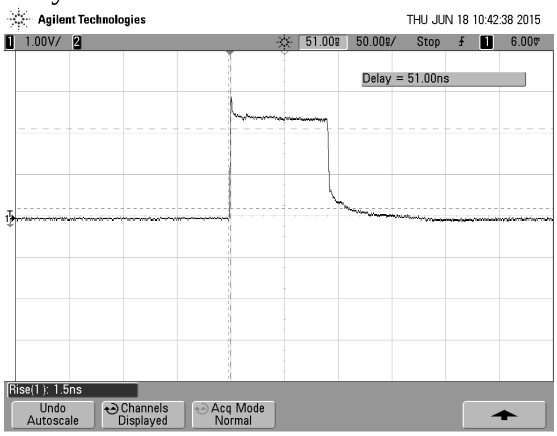

Fig. 6. The influence of dry reed relay on TLP

When the dry reed relay is not shielded, repeated testing found that the measured TLP rise time is usually 1.2ns and the minimum value is 1ns. When the dry reed relay is shielded and the rest of the test conditions remain unchanged, the measured TLP rise time is usually 800ps and the maximum measured value is 1ns. In comparison, after shielding, TLP rise time is more compliant, but the overshoot of the rising edge of TLP will be more obvious.

Fig. 4 is the TLP measured in the case of the dry reed relay without shielding. And Fig. 5 is the TLP measured with the same dry reed relay after shielded. Compared to Fig. 4, as mentioned above, the rise time of TLP is 800ps, less than 1ns, but the overshoot phenomenon is more obvious in Fig. 5.

Mercury relays shielded or not have the same results as described above.

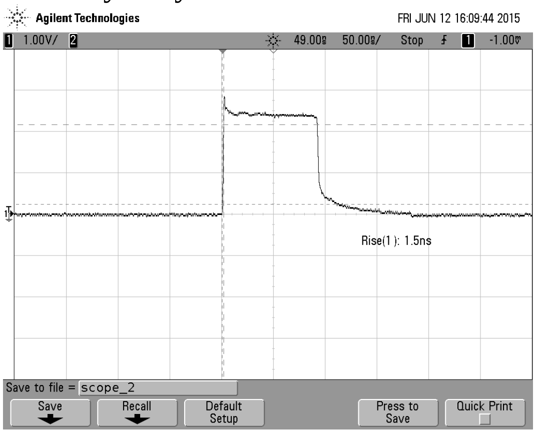

Fig. 7. The influence of mercury relay on TLP

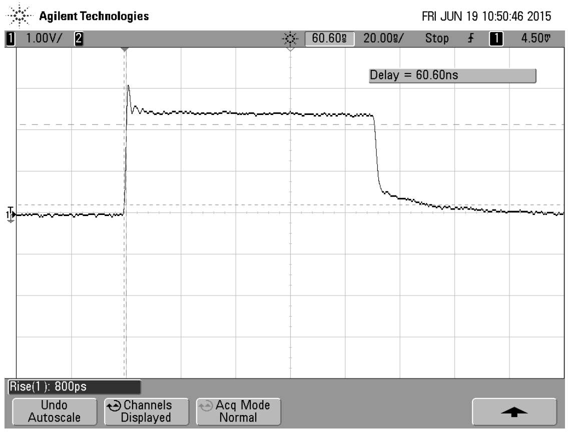

Fig. 8. The influence of L_2 on TLP

In the rest of the test conditions remain unchanged, only the relay is changed, TLP generated by mercury relays and dry reed relays can reach 800ps. There is nearly no difference on the impact of rising edge of TLP. Due to the presence of parasitic parameters, at the end of the falling edge of the square wave pulse TLP, there is a slow descent. Through Fig. 6 and Fig. 7 it can be seen that under the same conditions, the duration of the falling edge of the TLP used dry reed relay is shorter than that of TLP using mercury relays.

The influence of the pulse transmitting line. In the actual test, it found that the length of L_2 has a certain influence on the production of TLP. Fig. 8 is the TLP waveform with a 10cm L_2. Fig. 5 is the TLP measured without a L_2 and the rest conditions are the same with Fig. 8. Comparison between the two figures shows that both the rise times are 800ps, but because the length L_2 of Fig. 8 is longer, the overshoot of the rising edge is more obvious, and there is certain vibration phenomenon.

The influence of the load. In the actual test, a common metal film resistor is used as the load. In order to reduce the reflection of the wave caused by the impedance mismatch, the load resistance is 50Ω. As frequency spectrum of an ESD event reaches as high as Gigahertz, the parasitic parameters of the resistance lead will affect TLP.

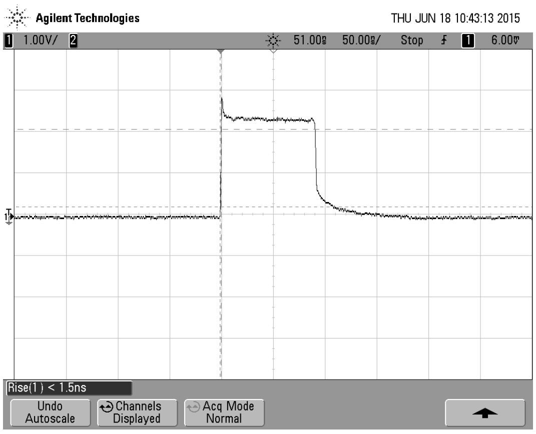

Fig. 9. Waveform of TLP with a short lead resistor

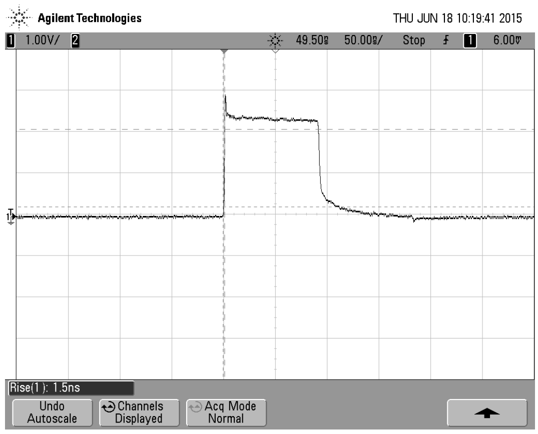

Fig. 10. Waveform of TLP with a long lead resistor

Fig. 9 and Fig. 10 are the TLP using the same load resistor with a shorter lead and a longer lead. The other conditions are the same. It can be seen that when the load resistor with a longer lead, there will be a small pulse projection at about the time of two pulse width while when the lead is shorter, the TLP waveform is smoother.

Repeated tests show that under the same conditions, when the load resistor lead is long, the measured TLP rise time is typically 1.2ns; a few cases can reach 1ns. The shortened load resistor lead, the measured rise time is usually 800ps, maximum measured is 1ns. In comparison, when the lead is short, TLP rise time can meet the requirement.

The influence of grounding wire of oscilloscope probe. In the test system, parasitic inductance can cause overshoot and ringing of TLP. In the actual test, the inductor is introduced mainly by oscilloscope probe ground wire. After shorten the length of the oscilloscope probe ground wire, the TLP can be well improved.

Fig. 11 is the TLP measured by the oscilloscope probe with a long ground wire. It can be seen that the rise time of TLP is 1.6ns, more than 1ns. And the overshoot phenomenon is very obvious. Fig. 5 is the TLP under the same conditions with that of Fig. 11 except the length of ground wire. It shows clearly that overshoot and oscillation have been significantly improved, and rise time can be easily controlled in less than 1ns. The rise time of Fig. 5 is 800ps.

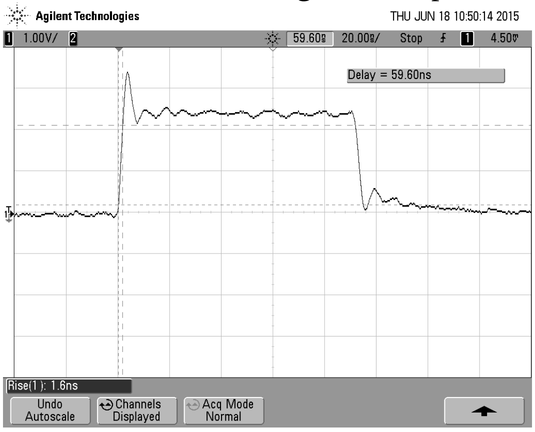

Fig. 11. Waveform of TLP with a long ground line of oscilloscope probe

Summary

Based on the principle of TLP, a test generator is build to study the influencing factors of TLP. Test results show that L_1 with different length generate TLP of different pulse width. With a relay shield, the rise time of TLP can reach 800ps, but it will bring overshoot to rising edge. The rise time can all achieve 800ps using mercury relay or dry reed relay. The two relays have little difference on the impact of the rise of TLP, but they have some influence on the falling edge. L_2 will bring overshoot and oscillation phenomenon to the rise edge. Shortening the lead of the load resistor can easily control the rise time within 1ns, which can meet with the needs easily. Longer oscilloscope probe ground wire will make the measured TLP has a phenomenon of oscillation and the rise time will be more than 1ns. After shortening the wire, TLP waveform can be improved.

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